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Albany, New York, Dudley Observatory.
Allegheny, Pennsylvania, Allegheny Observatory.
Armagh, Ireland, Armagh Observatory.
Berlin, Germany, Königl-Astronomisches Rechen Institut.
Berlin, Germany, Royal Observatory.
Cambridge, England, University Observatory.
Cambridge, Massachusetts, Harvard College Observatory.
Cape Town, Africa, Royal Observatory.
Christiania, Norway, University Observatory.
Cincinnati, Ohio, University Observatory.
Cordoba, Argentine Republic, National Observatory.
Dorpat, Russia, University Observatory.
Dublin, Ireland, Dunsink Observatory.
Dublin, Ireland, Royal Dublin Society.
Edinburgh, Scotland, Royal Observatory.
Geneva, Switzerland, Observatory.
Glasgow, Scotland, University Observatory.
Gotha, Germany, Ducal Observatory.
Goettingen, Germany, Royal Observatory.
Greenwich, England, Royal Observatory.
Hamburg, Germany, Hamburger Sternwarte.
Helsingfors, Russia, University Observatory.
Kasan, Russia, University Astronomical Observatory.
Kiel, Germany, University Observatory.
Kodaikanal, Palani Hills, South India, Observatory.
Koenigsberg, Germany, University Observatory.
La Plata, Argentine Republic, Observatory.
Leipzig, Germany, University Observatory.
Leyden, Holland, University Observatory.
Lisbon (Tapada), Portugal, Real Observatorio.
London, England, 26 Martin's Lane, British Astronomical Association.
London, England, British Museum.
London, England, Royal Astronomical Society.
London, England, 3 Verulam Bldgs., Gray's Inn, The Nautical Almanac.
Lund, Sweden, University Observatory.
Madison, Wisconsin, Washburn Observatory.
Madrid, Spain, Royal Observatory.
Marseilles, France, Observatory.
Melbourne, Victoria, Observatory.
Mexico, Mexico, Sociedad Cientifica "Antonio Alzate."
Milan, Italy, Royal Observatory.
Moscow, Russia, University Observatory.
Munich, Germany, Royal Observatory.
Naples, Italy, Royal Observatory.
New Haven, Connecticut, Yale University Observatory.
New York, New York, American Mathematical Society.

New York, New York, Columbia University Observatory.
Nice, France, Observatory.
Northfield, Minnesota, Carleton College Observatory.
Oxford, England, Radcliffe Observatory.
Oxford, England, University Observatory.
Paris, France, Bureau of Longitudes.
Paris, France, National Observatory.
Paris, France, Société Astronomique de France.
Philadelphia, Pa., 105 South Fifth St., American Philosophical Society.
Potsdam, Germany, Astrophysical Observatory.
Prague, Austro-Hungary, University Observatory.
Pulkowa, Russia, Imperial Observatory.
Rio de Janeiro, Brazil, Observatory.
Rome, Italy, Observatory of the Roman College.
Rome, Italy, Italian Spectroscopic Society.
Rome, Italy, Specula Vaticana.
San Francisco, California, California Academy of Sciences.
San Francisco, California, Technical Society of the Pacific Coast.
Stockholm, Sweden, University Observatory.
Strassburg, Germany, University Observatory.
Sydney, New South Wales, Observatory.
Tacubaya, Mexico, National Observatory.
Tokio, Japan, University Observatory.
Toronto, Canada, Astronomical and Physical Society of Toronto.
Toulouse, France, Observatory.
Turin, Italy, Observatory.
University Park, Colorado, Chamberlin Observatory.
University of Virginia, Virginia, McCormick Observatory.
Upsala, Sweden, University Observatory.
Vienna, Austria, Imperial Observatory.
Vienna (Ottakring), Austria, Von Kuffner's Observatory.
Washington, District of Columbia, Library of Congress.
Washington, District of Columbia, National Academy of Sciences.
Washington, District of Columbia, Naval Observatory.
Washington, District of Columbia, Smithsonian Institution.
Washington, District of Columbia, The American Ephemeris.
Washington, District of Columbia, U. S. Coast and Geodetic Survey.
William's Bay, Wisconsin, Yerkes Observatory.
Zurich, Switzerland, Observatory.

EXCHANGES.

Astrophysical Journal, William's Bay, Wisconsin.
Sirius, Cologne, Germany.
The Observatory, Greenwich, England.

FOR REVIEW.

[See *Publications*, A. S. P., vol. VIII, p. 101.]

The Call, San Francisco, California.
The Chronicle, San Francisco, California.
The Examiner, San Francisco, California.
The Mercury, San José, California.
The Record-Union, Sacramento, California.
The Times, Los Angeles, California.
The Tribune, Oakland, California.

A METHOD FOR DETERMINING THE VALUE OF AN AVERAGE SPACE OF A LATITUDE-LEVEL IN TERMS OF A MICROMETER-TURN.

By Frank Schlesinger.

In the determination of latitudes by means of the zenith-telescope it is necessary to know the average value of the spaces on the latitude-level. The following method has the advantage of being executed under precisely the same conditions that prevail during the observations for latitude themselves.

Two stars having nearly equal declinations and differing a few minutes in Right Ascension are selected. The telescope is pointed so that both will transit near the middle of the field, and micrometer-readings are taken upon each. Between the two transits, however, the telescope's inclination is changed so that the bubble of the latitude-level traverses several divisions. Consequently, the difference of micrometer-readings ($\Delta' R$) should be corrected by the difference of level-readings ($\Delta' l$), in order to obtain the true difference of declination ($\Delta\, \delta$) between the two stars. That is —

$$\Delta' R \pm \Delta' l = \Delta\, \delta$$

On a succeeding night the same observation is to be made upon the same stars, with this exception: the inclination of the telescope must be changed in the opposite direction between the two transits, so that if on the previous night the level-readings had been increased they must now be decreased, or *vice versa*. We now have,

$$\Delta'' R \mp \Delta'' l = \Delta\, \delta$$

As we may assume that the difference of declinations is the same as on the previous night, we get by subtraction,

$$\Delta'' R - \Delta' R = \Delta'' l - \Delta' l$$

This enables us to express one space of the level in terms of one turn of the micrometer, which is what was required. It will be noticed that accurate knowledge of the declinations is by no means necessary, and that therefore the two stars may be selected from the *Durchmusterung*. Indeed, suitable stars may usually be found by pointing the telescope quite at random in the meridian.

The following is a numerical example from actual observation. The zenith telescope employed, like all other modern ones, is provided with two latitude-levels; but for the sake of clearness data are given only for the upper one.

	Right Ascension.	Declination (1900).
Star 1	$9^h\ 14^m\ 50^s$	$+40^\circ\ 11'\ 40''$
Star 2	9 28 45	40 10 30

Level Readings.		Micrometer Readings.
North End.	*South End.*	
1900, April 8: Star 1		
5.9	28.6	15.5395
1900, April 8: Star 2		
13.8	36.6	13.0390
1900, April 9: Star 1		
16.0	37.8	15.2435
1900, April 9: Star 2		
5.4	27.4	13.2515

Hence, we have,

$$\Delta' R = 2.5005 \qquad \Delta' l = -\ 7.95 \text{ divisions}$$
$$\Delta'' R = 1.9920 \qquad \Delta'' l = +10.50$$

Consequently, one division of the level is equivalent to

$$\frac{0.5085}{18.45} = 0.0276 \text{ micrometer turns.}$$

Nine determinations similar to the above gave only $0^R.0004$ as the probable error of a single determination. This corresponds to $0''.016$, one turn of the micrometer being about $40''$.

The above method, appropriately modified, may also be applied to striding-levels of meridian instruments.

UKIAH, CALIFORNIA, January 22, 1901.

OBSERVATION OF *LEONIDS* AT POMONA COLLEGE, CLAREMONT, CALIFORNIA.

COMMUNICATED BY F. P. BRACKETT.

After the disappointment of last year, when an organized force of over fifty observers was trained for a campaign of at least a week, with charts and tables, and three photographic stations, and were met with almost total cloudiness all the week and a general failure of *Leonids* to attack all along the line, the astronomy class of Pomona College entered upon the observation of *Leonids* this year with more quiet and modesty. The plan of observation covered every night from November 12th to 17th, but the weather was so unfavorable that careful watch and record was kept only during the hours from 12 to 4 A.M. on the mornings of November 14th to 16th. This time was divided into periods of half an hour each, with three or more observers for each period. One noted the time of every call, a second kept the count, while the third mapped and described as many meteors as possible. Meteor paths were charted each night, but the limited knowledge of uranography and lack of experience on the part of the amateur observers rendered them unsatisfactory for the discussion of radiant points. Less than thirty were seen in *Leo* and the adjacent constellations, and over thirty in *Gemini*, *Auriga*, *Taurus*, and *Orion*, while nearly fifty were seen in the circumpolar constellations visible, chiefly in *Ursa Major*. Beside the *Leo* radiant, there seems to be one also in *Gemini* between α, β, τ, and T.

The results are exhibited chiefly in the accompanying tables.*

The whole number would, of course, have been much larger if there had been no moonlight. For the twenty periods during which they were seen, the average interval was five minutes; for the three periods from 12:30 to 2:00 Friday morning, it was $1^{m}\ 12^{s}$. Twice, a little before 2 o'clock, two were seen at once, and there were thirteen intervals of less than one minute. During all the remainder of the time there were only seven such intervals. Any attempt, however, to discuss the frequency of fall must be unsatisfactory because of the haze and cloudiness at times. More might have been seen during the later periods of the 15th and 16th if the sky had been clear, and the larger numbers in the second, third, and fourth period of the 16th may have been due to the absence of moonlight; yet the order of results is probably correct, and indicates that the greatest number fell on the 16th, and the least on the 15th. The large proportion of non-*Leonids* is noticeable.

About seventy-five, or three fifths, of the meteors observed

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* Table I, giving detailed description of the individual meteors is here omitted. The initials in the column "Observer" in Table II stand respectively for students CONE, KELSO, WARNER, BAKER, BIXBY, DAY, JENCKS, G. SMITH, STEWART, VOORHEES, BALDWIN, H. SMITH, MCFADDEN, LESTER, A. GOULD, T. GOULD, MOLES, MCLEAN, and STEFFA.

TABLE II.—RESULTS OF OBSERVATION BY PERIODS.

Date.	No.	Time.	No. of Meteors.	No. of *Leonids.*	Field.	Weather.	Observer.
Nov.		Begin. End.					
14	I	12:00 – 12:30	5	3	East......	Clear	C. K. W.
14	II	12:30 – 1:00	5	2	"	"	" " "
14	III	1:00 – 1:30	3	3	"	"	" " "
14	IV	1:30 – 2:00	11	3	"	"	" " "
14	V	2:00 – 2:30	7	5	E. N. & Z.	"	Ba. Bi. D.
14	VI	2:30 – 3:00	2	2	" "	"	" " "
14	VII	3:00 – 3:30	5	5	Whole sky	"	" " "
14	VIII	3:30 – 4:00	9	6	" "	"	" " "
15	IX	12:00 – 12:30	1	0	N. & E. ..	Cloudy except near the zenith.	J. Sg. St. V.
15	X	12:30 – 1:00	0	0	" " ..		" " " "
15	XI	1:00 – 1:30	2	1	" " ..		" " " "
15	XII	1:30 – 2:00	4	1	" " ..		" " " "
15	XIII	2:00 – 2:30	3	2	....		" " " "
15	XIV XV XVI	2:30 – 4:00	0	0	....	Cloudy......	Bl. Sh. Mf. L.
16	XVII	12:00 – 12:30	8	1	Whole sky	Hazy E. & S.	Ga. Gt. Mo. Mc. Sf.
16	XVIII	12:30 – 1:00	15	5	"	" "	" " "
16	XIX	1:00 – 1:30	13	2	"	" "	" " "
16	XX	1:30 – 2:00	13	6	"	" "	" " "
16	XXI	2:00 – 2:30	6	1	E. N. & Z.	Hazy........	Ba. Bi. D.
16	XXII	2:30 – 3:00	3	0	" "	More hazy...	" " "
16	XXIII	3:00 – 3:30	4	2	" "	" " ...	" " "
16	XXIV	3:30 – 4:00	1	1	" "	Cloudy......	" " "
			120	49			

TABLE III.

Time.	Total Number of Meteors.			Number of *Leonids.*		
A. M.	Nov. 14th.	15th.	16th.	Nov. 14th.	15th.	16th.
12:00 – 12:30 ..	5	1	8	3	0	1
12:30 – 1:00 ..	5	0	15	2	0	5
1:00 – 1:30 ..	3	2	13	3	1	2
1:30 – 2:00 ..	11	4	13	3	1	6
2:00 – 2:30 ..	7	3	6	5	2	1
2:30 – 3:00 ..	2	0	3	2	0	0
3:00 – 3:30 ..	5	0	4	5	0	2
3:30 – 4:00 ..	9	0	1	4	0	1
Total.....	47	10	63	27	4	18

were between the second and fourth magnitudes; twenty were of first magnitude and higher; six of class — 1, and one — 2.

Three fourths were white or yellow, in about the same proportion, and about five each of blue, green, orange, and red.

The duration of half were too swift for estimation, and nearly fifty more were seen for less than one second. Only five were visible for more than one second.

Both duration and length of path were doubtless shortened by moonlight and cloudiness. A course of some 30° and over was traced for about twenty, from 15° to 20° for about thirty, some 10° for about fifty, and a shorter course of 5° or 6° and less for about twenty.

ASTRONOMICAL OBSERVATIONS IN 1900.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

VARIABLE STARS.

*Z Cygni.**

March 23: Z = d.
30: id.
April 18: = e.
25: < e.
August 27: id.
October 16: = b.
21: id.
23: id.
28: id.
November 12: = a-
December 22 = c.

S Ursæ majoris.†

Jannary 25: S = d.
February 20: < c.
March 1: a little > d.
7: id.
14: id.
23: = e.
30: id.
April 18: $\left\{\begin{array}{l} < \text{e.} \\ \text{a little} > \text{f.} \end{array}\right.$
25: < e.
August 16: = e.
27: id.
29: id.
September 2: id.
13: $\left\{\begin{array}{l} < \text{d.} \\ > \text{e.} \end{array}\right.$
15: = d.
18: id.
25: id.
26: id.
October 14: $\left\{\begin{array}{l} > \text{d.} \\ < \text{c.} \end{array}\right.$
23: = d.
28. id.
November 11: a little < e.
December 22: < g.

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* *Vide* the sketch in the *Publications* A. S. P., No. 48, page 69.

† *Vide* the sketch in the *Publications* A. S. P., No. 73, page 56.

T Ursæ majoris. *

January 25: T = e.
February 20: > a (= 7.0 Mag.)
March 1: id.
7: id.
14: id.
23: id.
30: = a.
April 18: < a.
> b.
25: a little > c.
August 16: invisible.
27: < g.
29: id.
September 2: id.
13: id.
15: id.
18: id.
25: id.
26: id.
October 14: < e.
> f.
23: = d.
28: = c.
November 11: > a.
December 22: a little > a.

W Pegasi. †

January 25: W invisible.
February 20: id.
August 27: = e.
September 2; a little < e.
13: < e.
18: id.
26: = f.
October 14: < g.
23: id.
November 12: extremely faint,
December 22: invisible.

The Star BD. + 46°.2970.

When I observed the new variable BD. + 46°.2966 on October 28th, I was surprised to find that the star BD. + 46°.2970, which is very faint in the sketch by WILLIAMS (*Astron. Nachr.*, 3629) now was much brighter and = d in the sketch. On October 30th it was even > d, and it showed the same brightness on October 31st, November 10th, 11th, 12th, and December 22d. In *Astron. Nachr.*, 3673, Dr. ERNST HARTWIG has confirmed the remarkable change in brightness. The star is supposed to vary between the ninth and tenth magnitudes in a period not yet known.

SHOOTING STARS.

No.	Time.	Beginning.	End.	Mag.	Note.
	h m s	° °	° °		
1	Aug. 9, 10 16 15 P.M.	291 + 0	280 — 4	♀	Trair.
2	17 20	310 + 55	274 + 37	2	
3	21 20	32 + 75	250 + 82	2	
4	55 0	330 + 76	255 + 77	2	
5	11 11 0	348 + 63	318 + 74	3	

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* *Vide* the sketch in the *Publications* A. S. P., No. 22, page 63.

† *Vide* the sketch in the *Publications* A. S. P. No. 60, page 23.

6	19 50	17 + 17	11 + 14	1	
7	27 10	14 + 41	7 + 35	1	
8	29 15	6 + 26	347 + 17	♀	Yellow train.
9	30 0	11 + 58	359 + 57	3	
10	37 45	19 + 76	46 + 72	1	
11	11 40 20	355 + 46	4 + 38	2	
12	50 25	250 + 75	208 + 71	1	Red.
13	52 10	180 + 67	169 + 65	2	
14	56 50	354 + 52	5 + 44	3	
15	Aug. 11, 10 21 5	228 + 32	216 + 20	2	
16	22 40	8 + 34	17 + 37	♃	
17	27 30	2 + 21	351 + 13	2	
18	11 2 55	312 + 40	288 + 27	♀	Red.
19	14 0	28 + 50	38 + 42	3	
20	21 50	324 + 17	325 + 4	1	
21	28 0	135 + 66	156 + 57	2	
22	31 50	310 + 70	262 + 54	2	
23	37 0	252 + 28	235 + 27	2	
24	47 20	355 + 40	344 + 35	1	
25	57 40	270 + 36	261 + 18	1	
26	Aug. 20, 10 9 0	341 + 26	345 + 33	4	
27	19 10	322 + 62	280 + 39	2	
28	42 0	7 + 46	10 + 37	4	
29	43 40	298 — 7	302 — 16	2	
30	44 50	332 + 3	335 — 2	3	
31	45 0	337 + 10	332 — 1	3	
32	51 30	239 + 17	249 + 9	2	

No. 16. This meteor was also observed at Copenhagen: 184° + 63° (end point).

No. 20. Also observed at Copenhagen: 257° + 21° —> 255° + 10°.

No. 22. End point observed at Copenhagen: 227° + 31°.

The three meteors named have given the following results:—

No.	Beginning.			End.			Real Length of the Path.	Observer.
	h	λ	ϕ	h	λ	ϕ	β	
		° ′	° ′		° ′	° ′		
16	...	...	...	72	0 48	56 18	..	TORVALD KÖHL. OTTO ASMUSSEN.
20	99	1 48	55 18	71	1 47	55 11	32	TORVALD KÖHL. OTTO ASMUSSEN.
22	...	...	...	114	3 15	56 6	..	TORVALD KÖHL. OTTO ASMUSSEN.

⁂ h and β are expressed in kilometers; λ is W. long. from Copenhagen; ϕ is N. lat.; h is the altitude of the meteor above the Earth's surface.

Odder is situated in 2° 25′ W. long. from Copenhagen and 55° 58′ N. lat.

FIREBALLS.

In the past year fifteen fireballs have been seen from stations in Denmark.

No.	Time.			Beginning.	End.	Mag.	Station.	Note.
		h	m					
1	Jan. 1,	1	1 A.M.	140° + 35°	115° + 2°	♀	Odder..........	Train, lasting 5 seconds.
2	15,	5	27 P.M.	......	NNE. 45° alt.	*	Stubbeköping...	Explosion.
3	Feb. 8,	9	30	......	NNE. 45° alt.	*·	Otterup.........	Explosion.
4	May 3,	10	20	......	NW. 70° alt.	*	Himmelbjerg ...	Train, lasting for several seconds, illuminating the country.
5	June 14,	9	12	352° + 46°	331° + 32°	¼☾	Holbek.........	Explosion; blue; duration 2 to 3 seconds. Seen from several stations.
6	21,	10	30	Zenith.	NNW.	♀	Odder..........	Explosion.
7	Aug. 15,	8	40	......	246° — 17°	*	Holbek.........	Train, for 4 seconds. Same meteor was seen in Sonderburg, illuminating the town, and burst into 20 to 30 pieces.
8	Sept. 14,	11	15	......	NE. 12° alt.	*	Hellerup........	White.
9	Oct. 1,	8	59	......	ESE. 30° alt.	¼☾	Kolding........	Red.
10	20,	7	45	SW.	NE.	*	Lemvig.........	Red-yellow train.
11		10	30	......	W.	*	Birkeröd........	Train.
12	Nov. 5,	5	51	165° + 55°	209° + 26°	♀	Præstö	Very slow; durat'n 10 s.
13	9,	12	22 A.M.	78 — 11	82° — 16°	♀	Præstö	Train.
14	Dec. 16,	4	40 P.M.	......	S.W. 8° alt.	☾	Copenhagen....	Beautiful train, lasting a quarter to half an hour.
15		9	13	E.	S.	*	Snekkersten....	Explosion.

LARGE FIREBALL.

Among the meteors of this year No. 14 was of special interest. About this fireball, observed by thousands of men in Denmark, Northern Germany, and Holland, I received seventy-three letters from as many observers in the countries named. In the southern part of Sjælland the opinion of a large *comet* arose, because the train of the meteor lasted so long. Two observers at Copenhagen thought the phenomenon was only at a few miles distance, but as from *all* stations in Denmark it was standing near the horizon in the southwest, where the Sun lately had been setting, it was evident that the fireball must have passed over Northwestern Germany. This opinion was soon confirmed. From Hamburg and Bremen the phenomenon was seen rather in a *westerly* direction, from Wilhelmshafen to the *south*, from Amsterdam to the southeast, and from Cöln to the *north*.

The fireball lighted up the whole country, and thousands of spectators were frightened and looked astonished at the sparkling object that, like another moon, was traveling across the sky. In fact it is told that some children in a German village rushed into the house, crying: "Papa! Mama! Come out directly! The moon fell down from the sky just now, and is sticking in Minnermann's tree!"

The meteor whirled about on the last part of its path, then suddenly it burst into pieces with a rain of sparks, flashed up in a bluish light, dashed downward, and disappeared. Afterwards a large train was seen, at first forming a straight line, then a broken one like a lightning-flash. After that the figure of an S was seen and after twelve to fifteen (from Hamburg is said thirty) minutes the faint remainders of the train finally disappeared. It is not yet certain *where* the fireball fell to the ground, if it fell at all. Perhaps it took place in the southern part of Oldenburg.

In the past year a little transit-instrument (GUSTAV HEYDE, in Dresden) has been erected in the garden, and a wedge-photometer (JOEPFER, in Potsdam) for observations of variable stars has been attached to the 3-inch Steinheil refractor. Since 1900, April 1st, the private observatory at Odder has received a yearly grant from the Danish Government.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1901.

By MALCOLM MCNEILL.

MARCH.

The Sun is at the vernal equinox, and spring begins, March 20th, 11 P. M., P. S. T.

Mercury is an evening star at the beginning of the month, setting just about an hour after sunset, but it rapidly nears the Sun and passes inferior conjunction on March 7th. After that it is a morning star, rapidly moving away from the Sun, and by the end of the month is well out toward greatest west elongation, and rises about an hour before sunrise.

Venus is still nearer the Sun than during February, and at the end of the month rises only a few minutes before it. The interval is considerably shortened for points in the northern hemisphere by the fact that the planet arrives at its greatest heliocentric south latitude toward the close of the month, and is apparently several degrees south of the Sun. The conditions for visibility during the month are very poor.

Mars is the only one of the planets in good position for evening observation (except *Neptune*, which requires a telescope). It is above the horizon nearly the entire night, and its brightness makes it quite conspicuous, although toward the end of the month it has begun to be perceptibly less brilliant than it was during opposition in February. It increases its distance from the Earth about twelve millions of miles during the month, and at the end is about seventy-five millions from us. It moves about 7° westward and northward during the month in the constellation *Leo*, and on March 9th it passes about 4° north of *Regulus*, the brightest star of the constellation, and about 1° south of η *Leonis*, the star at the junction of handle and blade of the Sickle.

Jupiter and *Saturn* are still morning objects, but toward the close of the month they rise before 2 A. M. They are both in the constellation *Sagittarius*, a few degrees north of the group known as the Little Dipper. Their distance apart changes from about 6° on March 1st, to about 4½° on March 31st, *Jupiter* being somewhat higher up than *Saturn*.

Uranus rises about two hours earlier than *Jupiter* and *Saturn*, and is in the southern extension of *Ophiuchus*.

APRIL.

Mercury is a morning star throughout the month, and comes to greatest west elongation on April 3d. Its apparent distance from the Sun is then nearly 28°, which is 10° more than its distance at the greatest east elongation, in February; but as it is also nearly 12° south of the Sun, the maximum interval between the rising of the Sun and the planet is only a little more than an hour, and the conditions for visibility are rather poor.

Venus is very close to the Sun throughout the month — too near to be seen, unless under exceptional circumstances. It comes to superior conjunction on the afternoon of April 30th, and becomes an evening star, to remain so for ten months.

Mars is still in good position for evening observation, but is gradually losing its brilliancy. It increases its distance from the Earth about twenty millions of miles during the month, and on April 27th its distance from the Earth is the same as the Earth's mean distance from the Sun. It is in the constellation *Leo*, and after moving a little westward it turns and moves eastward from April 5th. At the end of the month it has moved about 3° from its westernmost position. It is also continually moving southward, so that as it comes back it travels on a line much nearer *Regulus* than during its westward motion. At the end of the month it is 1° west and 2° north of the star.

By the end of April *Jupiter* and *Saturn* rise before midnight. They are a little closer together than during March, and in the constellation *Sagittarius*. Both move slowly eastward until nearly the close of the month, *Saturn* until April 25th, and *Jupiter* five days longer. *Jupiter* is then a little more than 3° west and 0° 44′ south of *Saturn*. The third-magnitude star π *Sagittarii* lies a little north and between them. The opening of *Saturn's* rings is a trifle less than it was a year ago, but has not yet diminished much from the maximum.

Uranus rises before 10 P.M. at the close of the month. It is retrograding — moving westward, in the southern extension of *Ophiuchus*. No very bright star is near it, and it is not easy to make out.

Neptune is an evening object in the western sky on the border line between *Taurus* and *Gemini*.

EXPLANATION OF THE TABLES.—The phases of the Moon are given in Pacific Standard time. In the tables for Sun and planets, the second and third columns give the Right Ascension and Declination for Greenwich noon. The fifth column gives the local mean time for transit over the Greenwich meridian. To find the local mean time of transit for any other meridian, the time given in the table must be corrected by adding or subtracting the change per day, multiplied by the fraction whose numerator is the longitude from Greenwich in hours, and whose denominator is 24. This correction is seldom much more than 1^m. To find the standard time for the phenomenon, correct the local mean time by *adding* the difference between standard and local time, if the place is west of the standard meridian, and *subtracting*, if east. The same rules apply to the fourth and sixth columns, which give the local mean times of rising and setting for the meridian of Greenwich. They are roughly computed for lat. 40°, with the noon Declination and time of meridian transit, and are intended as only a rough guide. They may be in error by a minute or two for the given latitude, and for latitudes differing much from 40° they may be several minutes out.

MARCH–APRIL, 1901.

PHASES OF THE MOON, P. S. T.

Full Moon . . .	March 5,	12^h	4^m	A. M.
Last Quarter . . .	March 13,	5	6	
New Moon . . .	March 20,	4	53	
First Quarter . . .	March 26,	8	39	P. M.
Full Moon . . .	April 3,	5	20	
Last Quarter . . .	April 11,	7	57	
New Moon . . .	April 18,	1	37	
First Quarter . . .	April 25,	8	15	A. M.

THE SUN.

1901.	R. A.	Declination.	Rises.	Transits.	Sets.
Mar. 1,	$22^h\ 47^m$	− 7°44′	$6^h\ 39^m$ A.M.	$12^h\ 13^m$ P.M.	$5^h\ 47^m$ P.M.
11,	23 24	− 3 52	6 23	12 10	5 57
21,	0 1	+ 0 5	6 7	12 7	6 7
31,	0 37	+ 4 0	5 51	12 4	6 17
Apr. 10,	1 14	+ 7 48	5 35	12 1	6 27
20,	1 51	+ 11 22	5 20	11 59 A.M.	6 38
30,	2 28	+ 14 39	5 7	11 57	6 47

MERCURY.

1901.	R. A.	Declination.	Rises.	Transits.	Sets.
Mar. 1,	23 23	− 0 20	6 49 A.M.	12 48 P.M.	6 47 P.M.
11,	22 52	− 3 51	5 51	11 38 A.M.	5 25
21,	22 38	− 7 45	5 11	10 45	4 19
31,	22 58	− 7 56	4 52	10 25	3 58
Apr. 10,	23 38	− 4 57	4 43	10 26	4 9
20,	0 30	+ 0 25	4 38	10 39	4 40
30,	1 32	+ 7 32	4 35	11 1	5 27

VENUS.

1901.	R. A.	Declination.	Rises.	Transits.	Sets.
Mar. 1,	21 50	− 14 18	6 6 A.M.	11 17 A. M.	4 28 P. M.
11,	22 38	− 10 4	5 58	11 24	4 50
21,	23 25	− 5 23	5 49	11 31	5 13
31,	0 10	− 0 28	5 40	11 38	5 36
Apr. 10,	0 56	+ 4 31	5 29	11 44	5 59
20,	1 42	+ 9 20	5 18	11 50	6 22
30,	2 29	+ 13 47	5 11	11 58	6 45

MARS.

1901.	R. A.	Declination.	Rises.	Transits.	Sets.
Mar. 1,	10 15	+15 28	4 44 P.M.	11 38 P.M.	6 32 A.M.
11,	10 1	+16 26	3 48	10 45	5 42
21,	9 51	+16 55	2 57	9 56	4 55
31,	9 46	+16 54	2 13	9 12	4 11
Apr. 10,	9 46	+16 28	1 36	8 33	3 30
20,	9 51	+15 41	1 4	7 58	2 52
30,	9 59	+14 36	12 37	7 27	2 17

JUPITER.

Mar. 1,	18 34	—22 59	3 23 A.M.	8 0 A.M.	12 37 P.M.
Apr. 1,	18 51	—22 44	1 37	6 15	10 53 A.M.
May 1,	18 57	—22 39	11 44 P.M.	4 23	9 2

SATURN.

Mar. 1,	19 0	—22 10	3 46 A.M.	8 27 A.M.	1 8 P.M.
Apr. 1,	19 9	—21 58	1 52	6 33	11 14 A.M.
May 1,	19 11	—21 55	11 56 P.M.	4 37	9 18

URANUS.

Mar. 1,	17 2	—22 47	1 51 A.M.	6 29 A.M.	11 7 A.M.
Apr. 1,	17 3	—22 49	11 49 P.M.	4 27	9 6
May 1,	17 0	—22 45	9 48	2 26	7 4

NEPTUNE.

Mar. 1,	5 45	+22 11	11 49 A.M.	7 9 P.M.	2 29 A.M.
Apr. 1,	5 45	+22 13	9 48	5 8	12 28
May 1,	5 48	+22 15	7 53	3 13	10 33 P.M.

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope.)

I, D,	Mar. 3,	3h	11m	A.M.
I, D,	10,	5	5	
II, D,	11,	1	29	
II, D,	18,	4	2	
I, D,	19,	1	27	
I, D,	26,	3	21	
III, R,	29,	12	42	
I, D,	Apr. 2,	5h	5m	A.M.
I, D,	3,	11	43	P.M.
III, D,	5,	2	0	A.M.
III, R,	5,	4	41	
I, D,	11,	1	37	
II, D,	12,	12	58	
I, D,	18,	3	30	
II, D,	19,	3	31	
I, D,	25,	5	24	
I, D,	26,	11	53	P.M.
IV, D,	30,	11	15	
IV, R,	31,	12	1	A.M.

NOTE ON THE TIME OF RISING OR SETTING OF THE MOON.

By Sidney D. Townley.

Professor Young, in the 1898 edition of his "General Astronomy," added a method of computing the time of rising or setting of the Moon, (page 94, article 131). Since the method involves a transformation from sidereal to mean solar time I have found it less convenient than the following: Estimate as nearly as possible the Greenwich time of moonrise or moonset and take the Moon's Declination from the Ephemeris for that time. Compute the hour-angle with this value of the Declination using a zenith-distance of 90°. This hour-angle, corrected for the motion of the Moon in Right Ascension and for the gain of sidereal on mean solar time, subtracted from or added to the mean time of the Moon's transit (American Ephemeris, pages 408 to 415) gives the time of rising or setting. The correction to the hour-angle is easily obtained by multiplying the hour-angle by the "change per hour," found in the column adjacent to that of the mean time of transit. If the first estimate of the Moon's Declination is not very close, then the computation must be repeated.

The correction for semi-diameter, refraction and parallax is always small. Assuming the horizontal refraction to be 35′ then this correction in medium latitudes will range from two-tenths to one minute, depending upon the value of the parallax. For most purposes it is quite sufficient to assume five-tenths of a minute for this correction, which is to be added to the time of rising and subtracted from the time of setting.

If a series of values of risings and settings are to be computed for any particular place, then it will be convenient to construct a table for this correction. Likewise, a table for hour-angles ($Z = 90^\circ$) may be computed, with the Declination of the Moon as the argument.

(THIRTY-EIGHTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to M. Michel Giacobini, of the Nice Observatory, for his discovery of an unexpected comet on January 31, 1900.

The Committee on the Comet-Medal,

W. W. Campbell,
W. M. Pierson,
Chas. Burckhalter.

1901, January 14.

(THIRTY-NINTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to A. Borrelly, Adjunct Astronomer in the Observatory, Marseilles, France, for his discovery of an unexpected comet on July 23, 1900.

The Committee on the Comet-Medal,

W. W. Campbell,
W. M. Pierson,
Chas. Burckhalter.

Note. — This comet was independently discovered on the same night (July 23), but about five hours later in absolute time, by W. R. Brooks, of Geneva, New York; and the discovery was regularly and promptly announced.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

APPOINTMENT OF PROFESSOR W. W. CAMPBELL AS DIRECTOR OF THE LICK OBSERVATORY.

The Board of Regents of the University of California, at a meeting held in San Francisco on December 11, 1900, by unanimous vote, elected Professor W. W. CAMPBELL to be Director of the Lick Observatory.

As evidence of the general approval with which this action of the Board of Regents meets, we quote the following sentences from the note by Director GEO. E. HALE, of the Yerkes Observatory, in the December (1900) number of the *Astrophysical Journal*:—

> "The wisdom of this choice will be apparent to every one familiar with the circumstances of the case. The task which falls to the successor of Professor KEELER is no easy one, a fact which the Observatory Committee fully appreciated. They accordingly deferred action until the opinions of many eminent astronomers in this country and abroad could be secured. The replies, almost without exception, named Professor CAMPBELL as first choice. It is evident that his remarkable success as an investigator, his tireless energy, and his ability to direct the work of others are widely known and appreciated. It is a pleasure to extend congratulations to the President and Regents of the University of California for the wise manner in which the appointment was made, to the Lick Observatory for its bright prospects under such leadership, and to Professor CAMPBELL himself for the wider opportunity in the prosecution of his researches which he will now enjoy."

THE D. O. MILLS EXPEDITION TO THE SOUTHERN HEMISPHERE.

In the past five years, numerous references have been made in these *Publications* to the Mills spectrograph, an instrument presented to the Lick Observatory by the Hon. D. O. MILLS. This instrument, attached to the eye-end of the 36-inch refractor, has been used three nights per week in determining the velocities of the brighter stars in the line of sight. The main purpose of the investigation is to secure observational data from which to determine the speed and direction of motion of the solar system through space. In addition, it was hoped that the data secured would throw light on many of the fundamental questions relating to the constitution of the stellar universe, such as the distances of the stars, their grouping in families, etc. The results thus far obtained have shown that the field is one of unexpected richness. It may well occupy the attention, for an indefinite period, of the large number of observers and institutions now engaging in its development. Thus far we have secured observations of about 325 stars situated between the North Pole and 30° South Declination. The region south of 30° cannot be observed from Mt. Hamilton; yet the necessity of obtaining data somewhat uniformly distributed over the entire sky will be apparent to all who have considered the difficulties in the way of a satisfactory determination of the elements of the solar motion.

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* Lick Astronomical Department of the University of California.

For three or four years past I have hoped that, when the proper time came, this work could be extended to the South Pole, by means of a suitably equipped observing-station in the Southern Hemisphere. The rapid progress of the work at Mt. Hamilton made it desirable that the southern programme should be taken up at once. With the approval and indorsement of President WHEELER of this university, I laid my plans before Mr. MILLS, in November; and he at once stated that it would give him great pleasure to supply the funds to defray the entire expenses of the expedition. It is not often that an observatory receives such liberal support, in an ideal manner, for an ideal purpose. The Lick Observatory makes grateful acknowledgment of its indebtedness to Mr. MILLS's generosity at the present time and in the past.

In the next number of these *Publications* I hope to be able to give in some detail the plans of the expedition.

The observing-station will be selected with great care, probably in Chile or west of the Blue Mountains in Australia. In addition to a large proportion of clear nights, I should like to be assured of low relative humidity, a small range of night temperatures, little or no south night-winds, and fair accessibility.

W. W. CAMPBELL.

THE CROCKER ECLIPSE EXPEDITION TO SUMATRA.

The total solar eclipse of May 17, 1901, is one of the most important astronomical events of recent times, on account of its long duration. The path of totality crosses the islands of Mauritius, Sumatra, Borneo, Celebes, Ceram, New Guinea, etc. Its duration reaches a maximum of six and one-half minutes on the west coast of Sumatra. This is, I believe, the longest duration for any *observable* eclipse in the last half-century, since serious eclipse-work began; though eclipses of slightly longer duration have occurred on the ocean. It is a fortunate circumstance that on the west coast of Sumatra the eclipse occurs near noon, (at twenty-two minutes after local mean noon,) with the Sun only 21° from the zenith. While the weather conditions along the line are not of the best, yet they appear to be as promising in western Sumatra as in any of the islands farther east. This is likewise the region most accessible for observing-parties.

The Lick Observatory has had it in mind to prepare extensively for the suitable observation of this important eclipse. However, the reduced size of our observing-staff, and the pressure of work on the *Eros* campaign, made it impossible to plan for the expedition, until the middle of January.

It is a pleasure to announce that the Lick Observatory is again indebted to the generosity of WILLIAM H. CROCKER, Esq., who has offered, by virtue of his interest in the work, to defray all the expenses of an expedition to Sumatra.

The expedition plans to leave San Francisco on February 19th, traveling via Yokohama, Hong Kong, and Singapore. It should reach Padang, Sumatra, about April 10th. Assistant Astronomer C. D. PERRINE will be in charge, accompanied by one assistant from here. He will plan to secure the services of ten or twelve local assistants, during the week of the eclipse, from among the foreigners in Padang.

The long duration makes this the occasion for investigations on the corona, rather than on the edge of the Sun. It also affords unusual advantages for a search for unknown objects in the Sun's vicinity,—such as the planet, or planets, *Vulcan*. Accordingly, the work will be largely limited to these lines. I regret that we shall not be able to spare from the Observatory a spectroscopic observer; but I shall send one or two simple spectrographs along with the party, suitable for recording the coronal spectrum, hoping that the pressure of other work will not prevent their use. W. W. CAMPBELL.

A LIST OF EIGHT NEW SPECTROSCOPIC BINARIES.

The following eight spectroscopic binaries, discovered with the Mills spectrograph, are additional to the seventeen already announced in these *Publications*:—

12 Persei ($\alpha = 2^h\ 36^m$; $\delta = +39^\circ\ 46'$).

The binary character of this star was discovered in January, from the second spectrogram. The spectra of both components are visible on the first three plates, and are not very unlike. On the last plate the two spectra appear to be coincident.

Date.		Velocities.
1899	Dec. 19	-42^{km} and $\pm\ 0^{km}$
1900	Jan. 22	-3 " -54
	Jan. 26	-11 " -43
	Aug. 7	-27

The velocity of the system is about — 25 km per second.

ξ *Ursæ majoris* ($\alpha = 11^h\ 13^m$; $\delta = +32^\circ\ 06'$).

The principal component of this well-known double star has a variable velocity in the line of sight. ξ *Ursæ majoris* is therefore a triple system. The visible system is interesting historically, as having been the first one to show orbital motion, the two visible components forming a close and rapidly revolving system ($a = 2''.5$, $P = 60$ years). It has been observed with the micrometer very frequently since the beginning of the century, but no evidences of perturbative influences have been revealed by the measurements.

Date.		Velocity.
1897	Feb. 23	-8.4^{km}
	April 8	-15
1899	Feb. 22	-11.5
	April 5	-14.1
1900	Feb. 26	-21.9
	Mar. 9	-18.4
	Mar. 12	-19
	Mar. 14	-21.6
	Mar. 20	-20
	May 8	-18

The variable velocity was discovered early in March, from the fifth plate.

The spectrograms obtained in 1897 are rather poor, and will probably not be needed in the final discussion of the motion.

93 Leonis ($\alpha = 11^h\ 43^m$; $\delta = +\ 20^\circ\ 46'$).

The first two plates of this star were underexposed, but the discordance of eight kilometers afforded strong suspicion of its variable velocity. Two late plates confirmed the fact of its variability.

Date.		Velocity.
1900	Jan. 10	$+ 22^{km}$
	Jan. 16	+ 14 ±
	April 9	− 16
	May 14	+ 16

d Boötis ($\alpha = 14^h\ 06^m$; $\delta = +\ 25^\circ\ 34'$).

Date.		Velocity.
1900	Mar. 27	$+ 79^{km}$
	April 4	+ 3
	April 9	+ 11
	April 17	+ 60 ±

The variable velocity was discovered from the second plate.

β Scuti ($\alpha = 18^h\ 42^m$; $\delta = -\ 4^\circ\ 51'$).

Date.		Velocity.
1899	May 15	$- 17^{km}$
	June 11	− 11
1900	April 17	− 28
	April 23	− 29
	May 14	− 32
	July 18	− 31

The variable velocity was discovered from the third plate.

113 Herculis ($\alpha = 18^h\ 50^m$; $\delta = +\ 22^\circ\ 32'$).

Date.		Velocity.
1900	June 5	$- 35^{km}$
	July 9	− 21
	July 17	− 19
	July 31	− 16

The variation was discovered from the second plate.

2 Scuti ($\alpha = 18^h\ 37^m$; $\delta = -\ 9^\circ\ 09'$).

Date.		Velocity.
1899	June 14	$- 49^{km}$
	June 19	− 50
	July 3	− 45
1900	June 27	− 40
	July 3	− 38
	Aug. 1	− 49
	Aug. 12	− 38

The lines in this star's spectrum are rather broad, and cannot be measured very accurately. In addition, the third plate was underexposed; and the range of five kilometers in the approximate results for the first three plates afforded only a slight suspicion of variability. Its reality was established from the fourth plate.

η *Andromedæ* ($\alpha = 0^h\ 52^m$; $\delta = +\ 22^\circ\ 52'$).

Two components seem to be visible in the spectrograms of this star. The results for the principal components are:—

Date.			Velocity.
1899	Oct.	24	$-\ 25^{km}$
	Oct.	31	$-\ 26$
1900	July	24	$-\ 12$
	Aug.	8	$+\ 2$
	Sept.	9	$-\ 2$

The two component spectra appear to be practically coincident in the spectrogram of 1900, July 24th.

Mr. WRIGHT was in charge of the work with the Mills spectrograph during my connection with the Crocker Eclipse Expedition to Georgia, from March to late in July. While following the regular programme of observation, he detected the variable velocities of the stars ξ *Ursæ majoris*, *d Boötis*, β *Scuti*, *113 Herculis*, and *2 Scuti*, as described above; and the credit for these five discoveries belongs to him. W. W. CAMPBELL.

SOLAR PARALLAX OBSERVATIONS MADE AT THE LICK OBSERVATORY.

Observations of the planet *Eros* and of reference-stars, for determining the solar parallax, have been secured at the Lick Observatory, as follows:—

Astronomer R. H. TUCKER, assisted by Mr. R. T. CRAWFORD, Fellow in Astronomy, obtained two meridian-circle observations of each of the 319 reference-stars forming the first list in the Bulletin (No. 4) of the Conférence Astrophotographique Internationale. There have been made 1,100 observations in completing this list, including fundamental and circumpolar stars and nadirs. The reductions were completed, and the manuscript giving the results was ready for the printer, on December 21, 1900.

Mr. TUCKER has secured two observations of each of the 352 stars forming the second Conférence list. The completion of the second list has required about one thousand observations. The observations are all reduced to apparent place, and the mean-place reductions alone remain to be made. Mr. Crawford assisted on the first one-fifth of the programme.

Astronomer W. J. Hussey secured micrometer-measures of *Eros* with the 36-inch refractor, on eleven nights, from October 25th to December 12th. Forty-four complete observations were secured at large hour-angles east of the meridian, and fifty-five at large hour-angles west. One observation is composed of

4 micrometer-differences in Declination,
8 “ “ in Right Ascension,
4 “ “ in Declination,
involving sixteen micrometer-settings.

Assistant Astronomer R. G. Aitken obtained micrometer-measures of the planet with the 36-inch refractor on fifteen nights between October 21st and January 1st. He obtained forty-one complete observations at large eastern hour-angles, and forty-two at large western. Each observation is composed of

3 micrometer-differences in Declination,
10 “ “ in Right Ascension,
3 “ “ in Declination,
10 “ “ in Right Ascension,
3 “ “ in Declination,
involving twenty-nine micrometer-settings.

With the Crossley reflector, Assistant Astronomer C. D. Perrine, assisted by H. K. Palmer, Fellow in Astronomy, secured meridian-observations of *Eros* on sixty-one nights, between September 16th and January 18th. These are photographic, on 332 plates, five sets of images on each plate. Three hundred plates for parallax were obtained at large eastern hour-angles on thirty-four nights, and 220 plates at large western hour-angles on twenty-six nights. Many of the images on these plates are poor, and unavoidably so, on account of the defective mounting of the telescope. The great majority, however, are excellent, and only the best will be needed for measurement. Arrangements for measuring the plates, made with Professor Rees, Director of Columbia University Observatory, referred to in the last number of these *Publications*, leave no doubt that all the merits of these photographs will be utilized. No department of Astronomy is more promising, or is developing more rapidly, than that relating to the accurate determinations of star-positions from photographic plates. Columbia University Observatory has had a very extensive experience in this field, and is the only institution in this country with equipment and organization suitable for doing this work on a large scale.

Since the middle of December, the nights suitable for making *Eros* observations have been unusually few, even for winter months.

W. W. CAMPBELL.

1901, January 30.

A GIFT TO THE LICK OBSERVATORY.

The Committee of the National Academy of Sciences in charge of the Henry Draper Fund (for promoting research in astronomical physics) have made a grant of five hundred dollars to the Lick Observatory, to provide lenses, prisms, slit, materials, etc., for the construction of a thoroughly modern one-prism spectrograph.

The spectrographic work on faint spectra at this Observatory was done for several years with the original visual spectroscope, provided with photographic lenses. This was unsatisfactory, on account of the very large flexure effects during long exposures. Later, our one-prism spectrography has been done with a wooden-mounted instrument. The need of a first-class one-prism instrument has long been felt; and the generous gift from the Draper Fund will provide for its construction in the near future.

1901, January 30. W. W. CAMPBELL.

COMET NOTES.

Only three comets were discovered in the year 1900, all unexpected.

Comet *a* was discovered by M. GIACOBINI at Nice, on January 31, 1900. It was approaching the Sun rapidly when discovered, and in a few weeks was lost to observation, only reappearing on the other side of the Sun toward the end of May. The last observation made at this observatory was on July 22d. The comet's path was sensibly parabolic.

Comet *b* was discovered on July 23d by M. BORRELLY, at Marseilles, and independently by Dr. BROOKS, at Geneva, N. Y., a few hours later on the same night. It was a conspicuous object in a telescope of moderate aperture for several weeks, and at its brightest, was visible to the naked eye. A number of photographs of it were secured at the Lick Observatory, some of which will be reproduced in a future issue of these *Publications*. The comet was last seen with the 36-inch refractor on December 22, 1900, at which time it was estimated as being about equal to a 15th-magnitude star in brightness. Unfavorable weather has prevented any subsequent examination. It was found so close to its ephemeris position on the date mentioned that its path cannot vary sensibly from a parabola.

Comet *c* 1900, discovered by M. GIACOBINI, at Nice, on the night of December 20th, is still under observation, though it is already so faint as to be out of reach of small telescopes. The first three observations made at Mt. Hamilton, and the orbit based on them, will be found among the astronomical telegrams in this number. The elements resemble those of Comet 1857 IV sufficiently to indicate that the two comets may belong to the same family. If so, Comet *c* may prove to be a periodic comet of long period; but further observations are needed before this point can be decided.

FINLAY'S periodic comet, which returned to perihelion early in the year 1900, was not detected, owing probably to its unfavorable position. According to the calculations of M. SCHULHOF, it will be much more favorably placed in 1906, when it will approach within twenty million miles of the Earth.

BARNARD'S comet of 1884 also escaped detection, as at its previous return in 1890 and 1895.

E. SWIFT'S comet of 1894, which may be identical with DE VICO'S comet of 1844, returns to perihelion on February 13th of the present year, and may perhaps be found after perihelion passage. So far it has not been seen, though it, as well as BARNARD'S comet, was carefully looked for by Mr. PERRINE with the 36-inch refractor.

There are several other interesting periodic comets that may be observed during the present year, viz: BRORSEN'S, which should return to perihelion this month; DENNING'S (1894), ENCKE'S, and BROOKS'S of 1886, whose perihelion passage occur in August and September, 1901, and January, 1902, respectively.

Mr. DENNING, in *Knowledge*, has called attention to the curious fact that during the century just closed, one or more large naked-eye comets were seen at intervals of about 19½ years — in

1823, 1843, 1862, and 1881. Those who are interested in this line of work will sincerely hope that later writers may be able to add the year 1901 to this list. R. G. AITKEN.

ASTRONOMICAL TELEGRAMS.

(Translations.)

CAMBRIDGE, MASS., Dec. 8, 1900.
To W. W. CAMPBELL: (Received 3:05 P.M.)

DOUGLAS, of the Lowell Observatory, telegraphed last night that a projection was seen on the north edge of *Icarium Mare** that lasted seventy minutes. (Signed) E. C. PICKERING.

BOSTON, MASS, Dec. 24, 1900.
To Lick Observatory: (Received 9:20 A.M.)

A comet was discovered by M. GIACOBINI at Nice, on December 20.313, G. M. T., in R. A. $22^h\ 32^m$, and Decl. $-22°\ 0'$ (approximate position). Its daily motion is $+1°30'$ in R. A., and $-8'$ in Decl. (Signed) JOHN RITCHIE, JR.

LICK OBSERVATORY, Mt. Hamilton, Cal.,
To Harvard College Observatory, Dec. 24, 1900.
Cambridge, Mass., (Sent 8:20 P.M.)
To Students' Observatory, Berkeley, Cal.:

Comet Giacobini was observed by R. G. AITKEN on December 24.6022, G. M. T., in R. A. $22^h\ 59^m\ 10^s.2$; Decl. $-22°\ 44'\ 41''$
(Signed) W. W. CAMPBELL.

CAMBRIDGE, MASS., Dec. 25, 1900.
To Lick Observatory.: (Received 8:30 A.M., Dec. 26.)

Kiel cables that Comet *c* (GIACOBINI) was observed at Nice on Dec. 24.271, G. M. T., in R. A. $22^h\ 57^m$; Decl. $-22°\ 45'$. Approximate position. (Signed) EDWARD C. PICKERING.

LICK OBSERVATORY, Mt. Hamilton, Cal.,
To Harvard College Observatory, Dec. 27, 1900.
Cambridge, Mass., (Sent 1:57 P.M.)
To Student's Observatory, Berkeley Cal.:

Comet Giacobini was observed by R. G. AITKEN on December 26.6280 in R. A. $23^h\ 11^m\ 23^s.6$; Decl. $-22°\ 57'\ 59''$.
(Signed) W. W. CAMPBELL.

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* *Icarium Mare* is in Martian Longitude 320°-345° and Martian Latitude + 30°±.

LICK OBSERVATORY, Mt. Hamilton, Cal.,
To Harvard Observatory, Dec 28, 1900.
Cambridge, Mass., (Sent 10:55 P.M.)
To Student's Observatory, Berkeley, Cal.:

Comet Giacobini was observed by R. G. AITKEN on Decem-28.6198 in R. A. $23^h\ 23^m\ 18^s.5$; Decl. $-\ 23^\circ\ 7'\ 27''$.

(Signed) W. W. CAMPBELL.

LICK OBSERVATORY, Mt. Hamilton, Cal.,
To Harvard College Observatory, Dec. 31, 1900.
Cambridge, Mass.: (Sent 4:15 P.M.)

From the Lick Observatory observations of December 24, 26, and 28, elements and ephemeris [here omitted] of Comet *c* 1900 (GIACOBINI) were computed by R. G. AITKEN as follows:—

$$\begin{array}{rl} T = & \text{December } 1.41 \text{ G. M. T.} \\ \left.\begin{array}{r} \omega = \\ \Omega = \\ i = \end{array}\begin{array}{l} 175^\circ\ 54' \\ 192\ \ \ 39 \\ \ \ 31\ \ \ \ 1 \end{array}\right\} & 1900.0 \\ \text{natural } q = & 0.9769 \end{array}$$

(Signed) W. W. CAMPBELL.

[The Lick Observatory positions of Comet *c* for the dates December 24th and 28th, as printed in *Science Observer*, *Special Circular*, *No. 128*, are slightly in error owing to a mistranslation in each telegram of the cipher-word giving the seconds and tenths of seconds of R. A., the seconds of N. P. D., and the fourth decimal of the date. Both messages were sent correctly from the Lick Observatory, and were transmitted correctly by the Western Union Telegraph Company in San José. The correct translations are printed above.]

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

Dr. LEWIS SWIFT has disposed of his astronomical equipment to the Pasadena and Mount Lowe Railway. The instruments are to remain on Echo Mountain, and Professor E. L. LARKIN is now director of the observatory.

The oft-recurring discussion concerning the management of the United States Naval Observatory is again before the public. The discussion was precipitated by the publication of the report of the Superintendent of the United States Naval Observatory for the fiscal year ending June 30, 1900. In it Superintendent DAVIS takes occasion to criticise rather severely the actions and report of the Board of Visitors appointed by Secretary LONG in 1899. Replies to these criticisms have appeared as editorials and communications in *Science*, January 4th, 11th, and 18th. The discussion has now reached such a point that its continuation will be productive of very little good. A great many astronomers think the present management of the Observatory is fundamentally wrong. It is to be hoped that they will soon make a determined effort to have the Observatory reorganized, or else keep still and give the new staff a chance to show what it can do.

Volume XVIII of the *Publications of the National Observatory of the Argentine Republic* has been received recently. It is a continuation of the Southern Durchmusterung, and contains a catalogue of 149,447 stars, being all the stars down to the tenth magnitude in the zone 42° to 52° South Declination. It is a matter of congratulation that Dr. THOME, notwithstanding many difficulties, financial and others, has been able to bring the third part of this great work to completion.

At the annual public meeting of the Paris Academy of Sciences, held on December 17, 1900, the following prizes were awarded for astronomical work: The Lalande prize, to M. GIACOBINI, of Nice, for his work on comets; the Damoiseau prize, to M. J. VON HEPPERGER, for his work on the influence of the planets on comets; the Valz prize, to M. l'Abbé VERSCHAFFEL, for work done at the Abbadia Observatory; and the Janssen prize, to Professor BARNARD, for the discovery of the fifth satellite of Jupiter.

The *Astrophysical Journal* for December contains an important article, by Professor EDWIN B. FROST, on the spectroscopic and photographic work of the Yerkes Eclipse Expedition (May, 1900). The conclusions reached are summarized as follows:—

"The experience, principally of Sir NORMAN LOCKYER and Mr. J. EVERSHED, is confirmed, that useful results may be obtained, without much risk of failure, by the employment of the simple objective-prism camera.

"It is shown that the concave grating, used direct, without intervention of mirrors or lenses, will furnish sufficiently bright images of the flash spectra, and probably of the corona, for useful measurement and discussion.

"It appears that spectra photographed with such instruments just before or after totality (within about thirty seconds of the times of contact), yield quite as valuable results as those taken at the precise instants of contact.

"It is demonstrated that the stronger dark-lines of the solar spectrum are in a large proportion reversed in a narrow stratum at the base of the chromosphere, and the evidence indicates that this is equally true of the fainter lines.

"The differences in intensities of the bright and dark lines are chiefly due to an increase in the intensities of the former, especially for such elements as strontium, rather than to a decrease in the intensities of the latter.

"The chemical origin of the dark lines which are reversed is found in elements which are among those most numerously represented in the spectrum. This tends to show that the reversal is not an inherent peculiarity of special elements, but rather a phenomenon of lines in general."

Continuing the plan inaugurated last year letters were recently sent to the directors of the observatories of the Pacific Coast, asking for a statement of the work accomplished during 1900. From the answers received the following accounts have been written:—

CHABOT OBSERVATORY.—Instruction in connection with the schools of the city of Oakland has continued, as in former years, to be the chief work of this Observatory. A lecture-hall, to be used for school and general educational purposes, has recently been erected adjoining and communicating with the Observatory. The hall is about seventy-five feet long and provided with six hundred opera-chairs. Very complete arrangements have been made for heat, ventilation, and light. Arc-light and solar-projection lanterns have been provided for the use of lecturers. Considerable of Mr. BURCKHALTER'S time during 1900 was taken up in connection with the eclipse of May 28th, which he successfully observed at Siloam, Georgia. An account of his expedition, together with some reproductions of the photographs taken, may be found in No. 75 of these *Publications.*

INTERNATIONAL LATITUDE OBSERVATORY.—Latitude observations were continued at the Observatory in Ukiah without interruption during 1900. Dr. SCHLESINGER's report of the work accomplished is as follows:—

"The programme of the International Geodetic Association for observing Variations of Latitude has been continued without modification at this station, as well as at the five others, throughout 1900. An account of the programme is to be found in No. 71 of these *Publications.* Below is given a summary of the observations made here during the year:—

"I. *Observations for Latitude proper.*—The following table shows the number of nights and the number of pairs observed in each month:—

January . . .	15 nights . . .	179 pairs
February . .	13 " . . .	168 "
March	14 " . . .	182 "
April	11 " . . .	154 "
May	18 " . . .	208 "
June	13 " . . .	169 "
July	15 " . . .	209 "
August	14 " . . .	188 "
September . .	14 " . . .	166 "
October . . .	14 " . . .	181 "
November . .	13 " . . .	123 "
December . .	14 " . . .	176 "
Totals . .	168 nights	2,103 pairs

"These numbers include 'refraction pairs' (about twenty per cent. of the total), which are not used for determining the latitude, but to detect possible anomalies in the refraction.

"II. *Observations for the control of the position of the instrument.*—This work has been much simplified by the use of the meridian-marks. These having once been set in place, the azimuths are held in excellent control. Although observations were frequently made to test the adjustment of the marks, the latter might have been assumed correct throughout the entire year without incurring any appreciable error in the latitude. Similarly, the collimation and lateral flexure have remained sensibly constant; the former varied only $0^s.10$ from its mean value during the year.

"III. *Observations for values of the level spaces.*—Nine tests were made for each of the two levels with which the zenith-telescope is provided. These tests are based upon the star observations by a method described on another page of this publication.

"IV. *Observations for micrometer value.*—Two series of observations for this purpose were executed; one on circumpolar stars near elongation, the other upon stars in the *Pleiades* whose differences of declinations have been well determined, especially by BESSEL, ELKIN, and JACOBY.

"V. *Observations for screw-errors.*—The progressive errors of the screw were determined by suspending a vertical scale at some distance from the telescope and then determining the errors of the scale and the screw simultaneously. A more detailed account of this investigation will be given later.

"A definitive reduction of the observations made at all the stations up to 31st December, 1900, is now in progress at Potsdam, and will shortly be published. A preliminary reduction, already made, gives promise of unprecedented accuracy in the determination of the path of the Earth's pole of rotation upon its surface."

LICK OBSERVATORY.—Through the "Notices from the Lick Observatory," the readers of the *Publications* are kept well informed concerning the work carried on in that institution. During the past year, in addition to the regular work of the Observatory, an eclipse expedition to Georgia was undertaken by Dr. CAMPBELL and Mr. PERRINE. These two observers were assisted by about a dozen volunteer workers, and a large programme of work was successfully carried out in the short time of totality. A general account of the expedition was printed in No. 75 of these *Publications*, and the more detailed account will be issued later by the Observatory.

Professor KEELER'S second annual report, written only a few weeks before his death, has recently been published in President WHEELER'S biennial report to the Governor of the State. The report contains, in some detail, an account of the work being carried out with the various instruments. Extracts, concerning the work with the two largest instruments, are given below. "About half the time of the 36-inch equatorial is devoted to spectroscopic determinations of the motions of stars in the line of sight, with the aid of the Mills spectrograph. This department of the scientific work of the Observatory, which is probably as important as any work that can be done at the present time with a large telescope, has been admirably systematized by Dr. CAMPBELL, who is assisted in the observations and reductions by Mr. WRIGHT. The probable error of a single determination is only about 0.25 km. for the best stars, a degree of accuracy which has never before been reached in such measurements. A correcting-lens, which is placed in the cone of rays from the 36-inch objective, and which changes the chromatic aberration of the telescope so as to adapt it to photographic work, has added somewhat to the accuracy and very much to the convenience of the observations. . . . For the remaining half of the time the telescope has been used for micrometric work by Mr. HUSSEY, Mr. PERRINE, and Mr. AITKEN, and occasionally by other observers. Series of observations of the satellites of *Neptune* and *Mars* have been made by Mr. HUSSEY; of the satellites of *Neptune* and *Uranus* by Mr. AITKEN. A hundred and fifty sets of measures of planetary nebulæ, for parallax, and a set of measures for determining a possible refractive effect on stars by the head of SWIFT'S comet, have been made by Mr. PERRINE. . . . . Observation with the Crossley reflector is subject to more limitations than observations with the other instrument. Work cannot be pursued on moonlight nights, in slightly foggy, or even in damp weather. Nevertheless, about seventy photographs have been made of forty different nebulæ and star-clusters, mostly with long exposures of from three to four hours each, and from the most interesting of these, positive enlargements have been made on glass. The definition of these photographs, and the amount of detail shown by them, are surprising. Many new features are shown, and some general conclusions of the highest interest have already been drawn. From one to sixteen new nebulæ have been found on nearly every plate exposed, and I have estimated that the number of new nebulæ in the sky, within reach of the Crossley reflector, may be something like 120,000."

MOUNT LOWE OBSERVATORY — Dr. SWIFT, owing to advanced age, did but little astronomical work during 1900. As stated in another place in these notes, Dr. SWIFT has disposed of his astronomical outfit, and Professor EDGAR L. LARKIN, formerly Director of the Knox College Observatory, Galesburg, Ill., is now Director of the Mount Lowe Observatory. Professor LARKIN took charge of the observatory January 1, 1901, and writes that he is now engaged in reorganizing the observatory, making necessary repairs, etc. When all of the necessary changes are made he expects to give his time to spectroscopic work, mostly upon the Sun.

NAVAL OBSERVATORY.— Mare Island.— Lieutenant GUY W. BROWN, U. S. Navy, writes that owing to many duties as a naval officer, no astronomical work other than that of maintaining the time-service of the Pacific Coast was attempted at Mare Island.

STUDENTS' OBSERVATORY.—The work at the Students' Observatory, Berkeley, is nearly all in the line of instruction, and the time of the members of the staff is given to directing and supervising the work of students rather than to research work. During the last two years a much closer relation between the Berkeley and Lick Astronomical Departments of the University has been established. It has been Professor LEUSCHNER'S ambition to build up here, in connection with the Lick Observatory, a thorough School of Astronomy. During the past year a comprehensive course of study, both undergraduate and graduate, has been outlined, and a special announcement to students is now being printed. We hope to give a more detailed account of this in the next number of these *Publications*. During the first term of 1900, the total enrollment in astronomical courses was 130, and during the second term 120. Among the special lines of work carried out during the past year, the following may be mentioned: Computation, by Professor LEUSCHNER and Miss HOBE, of the orbit of a faint asteroid discovered by Professor KEELER with the Crossley Reflector, June 28, 1900; computation of the elements of the Crossley asteroid 1899 FD, by Mr. PALMER and Mr. PHIPPS; notes on the computation of preliminary orbits (*A. N.* No. 3669) by Mr. SPRAGUE; adaptation to long intervals of VON OPPOLZERS' method of computing comet orbits from four observations, by Mr. KUNO.

UNITED STATES COAST AND GEODETIC SURVEY OBSERVATORY.— This observatory, situated in the Presidio Reservation, San Francisco, and provided with a transit and a zenith-telescope, is used as a longitude base for the determination of new stations by telegraphic time-signals and for practice of observers. Captain AUG. F. ROGERS, Assistant in Coast Survey, and in charge of the observatory, writes, however, that no new determinations were made during 1900.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, JANUARY 26, 1901, AT 7:30 P. M.

Mr. BURCKHALTER presided. A quorum was present. The minutes of the last meeting were approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED JANUARY 26, 1901.

Mr. B. A. BAIRD	U. S. Coast and Geodetic Survey, P.O. Box 2512, S.F., Cal.
Mr. C. F. DE MOTT	P. O. Box 400, Hempstead, Nassau Co., N. Y.
Mr. E. B. LEAMING	Rooms 13 & 14, 4th floor, Mills Building, S. F., Cal.
Prof. A. O. LEUSCHNER	2011 Bancroft Way, Berkeley, Cal.
Mr. C. E. SANGER	932 E St., San Diego, Cal.
Dr. FRANK SCHLESINGER	Ukiah, Cal.
Mr. V. STRÓYBERG	Observatory, Copenhagen, Denmark.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE LECTURE HALL OF THE CALIFORNIA ACADEMY OF SCIENCES, JANUARY 26, 1901, AT 8 O'CLOCK P. M.

Mr. BURCKHALTER presided. The minutes of the last meeting were approved.

The following papers were presented:—

1. The Determination of the Motion of the Solar System, from Observations with the Mills Spectrograph, by Prof. W. W. CAMPBELL.
2. Planetary Phenomena for March and April, 1901, by Prof. M. MCNEILL.
3. A Method for Determining the Value of an Average Space of a Latitude-Level in Terms of a Micrometer-Turn, by FRANK SCHLESINGER.

A committee to nominate a list of eleven Directors, and committee on Publication, to be voted for at the annual meeting, to be held on March 30th, was appointed as follows: Messrs. D. S. RICHARDSON, (chairman), J. COSTA, M. MULLANY, C. F. A. TALBOT, L. H. PIERSON.

A committee to audit the accounts of the Treasurer, and to report at the annual meeting in March, was appointed as follows: Messrs. WM. H. LOWDEN (chairman), O. VON GELDERN, F. H. MCCONNELL.

The chairman then introduced Professor CAMPBELL, the lecturer of the evening, who gave an account, illustrated by lantern-slides, of the progress of the work being done at the Lick Observatory on the determination of the Motion of the Solar System, from observations with the Mills Spectrograph.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. James E. Keeler*	*President*
Mr. Charles Burckhalter	*First Vice-President*
Miss R. O'Halloran,	*Second Vice-President*
Mr. S. D. Townley	*Third Vice-President*
Mr. C. D. Perrine Mr. F. R. Ziel	*Secretaries*
Mr. F. R. Ziel	*Treasurer*

Board of Directors—Messrs. Burckhalter, Campbell, Dolbeer, Hill, Keeler,* Molera, Miss O'Halloran, Messrs. Perrine, Pierson, Townley, Ziel.

Finance Committee—Messrs. Pierson, Burckhalter, Hill.

Committee on Publication—Messrs. Aitken, Townley, von Geldern.

Library Committee—Mr. Townley, Miss O'Halloran, Miss Hobe.

Committee on the Comet-Medal—Messrs. Keeler* (*ex-officio*), Pierson, Burckhalter.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Francisco Rodriguez Rey.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

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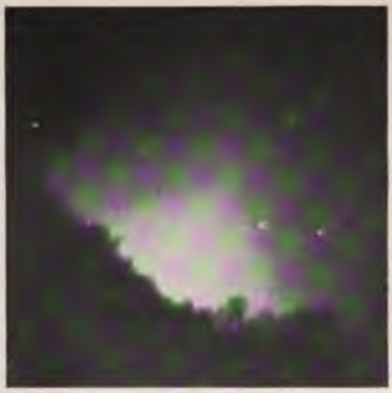
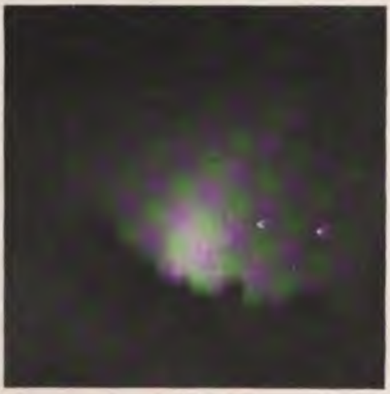
* Deceased.


(1)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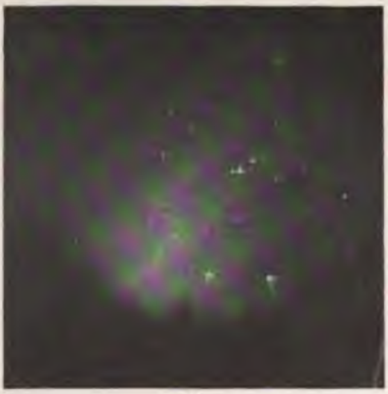
(3)

THE ZODIACAL LIGHT IN *PISCES*.
Lowell Observatory, Feb. 13, 1901.
Exposure times: (1) = $7^m.5$; (2) = 15^m; (3) = 30^m.

THE
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PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XIII. SAN FRANCISCO, CALIFORNIA, APRIL 1, 1901. NO. 78.

PHOTOGRAPHS OF THE ZODIACAL LIGHT.

BY A. E. DOUGLASS.

The accompanying photographs of the western zodiacal cone were made by the writer on February 13, 1901. The lens was made by ALVAN CLARK & SONS in 1899 especially for this purpose. It has the Fraunhofer curves. Its clear aperture is 0.9, inch and its focus 1.8 inches, a ratio of 1 : 2. The mounting used in this work is largely home-made, consisting of a powerful Seth Thomas clock-movement, working into a cog-wheel having 120 teeth, attached to an inverted altazimuth mounting belonging to a two-inch telescope.

Previous to February 13th a number of photographs had been obtained with this apparatus, by exposures of an hour or more. On that date, however, trials of short exposures were made with immediate success. It appears that when the Zodiacal Light is at its best, exposures of eight minutes are ample; at its worst, thirty minutes are required, as for the Gegenschein. Impressions of the Gegenschein have almost certainly been obtained, but more experimenting is necessary before successful prints can be made.

Trials of some eight or ten different developers have been made, with the result, thus far, that two may be used with safety, a fairly strong glycin developer and a hydrochinon developer with about twenty-five drops of bromide solution for every two ounces, and perhaps a few drops of a ten-per-cent. solution of yellow prussiate of potash. The development with the glycin may be carried on for almost any length of time without fogging, but it is largely finished in thirty minutes. The development in the hydrochinon may be continued for thirty minutes, or until the plate fogs. As far as the trials go, the glycin is slightly better than the hydrochinon.

The first negative obtained at this observatory, showing the Zodiacal Light, was on March 10, 1899. Many different lenses were tested, and a number of satisfactory negatives were obtained, of which one of the best was of the eastern cone, on October 7, 1899. This was reproduced in *Popular Astronomy*, No. 74, April, 1900. But the engraving did not by any means equal the photographic print. And, besides that, the original exposures before the present year were all made by hand-following. This tedious work was done nearly always by Mr. W. A. COGSHALL.

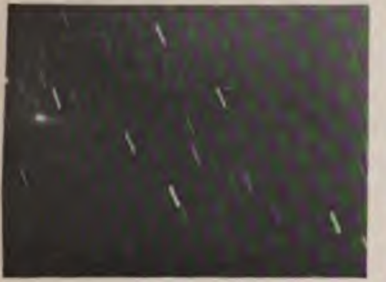
LOWELL OBSERVATORY,
FLAGSTAFF, ARIZONA, March 11, 1901.

PHOTOGRAPHIC OBSERVATIONS OF COMET II, 1900 (BORRELLY–BROOKS).

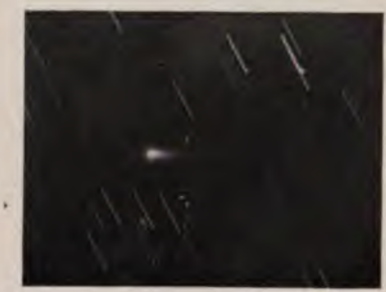
BY H. K. PALMER.

This comet was discovered by BORRELLY, at Marseilles, and independently by BROOKS, at Geneva, N. Y., on July 23, 1900. At the time of its discovery it had a bright stellar nucleus of about the 6½ magnitude. It was first observed at the Lick Observatory on July 24th, and was found to be bright enough to warrant a series of photographs. Accordingly, on the 25th, this series was begun, and was continued until August 4th, when the Moon interfered. By the time the Moon was out of the way the comet had become so faint that further photographic observations were impossible.

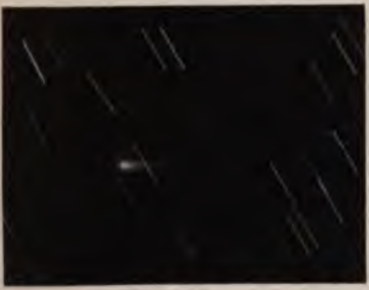
On July 25th, the comet was photographed with the Crocker telescope, but on all succeeding nights, except August 4th, with a Willard lens attached to the five-inch Floyd telescope. The latter was used as a guiding telescope. Both the Crocker and the Willard lenses have apertures of six inches. The focal length of the Crocker is 30.82 inches, while that of the Willard lens is only 25.99 inches. On the photograph taken with the Crocker telescope, 1 degree = 0.538 inch; and on those taken with the Willard lens, 1 degree = 0.454 inch. The photographs



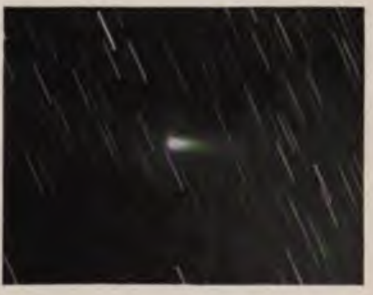
July 25. Exp. $1^h\ 10^m$.



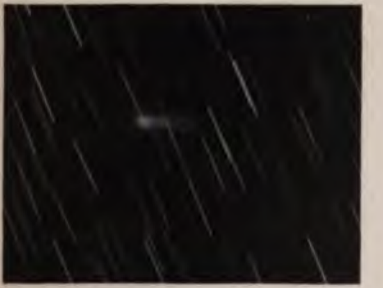
July 27. Exp. $2^h\ 15^m$.



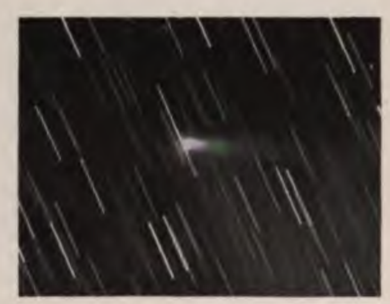
July 29. Exp. $2^h\ 29^m$.



July 31. Exp. $2^h\ 6^m$.



Aug. 2. Exp. $3^h\ 2^m$.



Aug. 3. Exp. $3^h\ 9^m$.

COMET 1900 II. (BORRELLY-BROOKS).

shown here have all been enlarged to the uniform scale of 1 degree = 0.75 inch.

The usual method of guiding these telescopes is to keep the head of the comet on the intersection of two coarse, dark cross-wires in the focus of the guiding telescope. The nucleus of this comet was so small that it was completely hidden by the wires, leaving nothing but the diffuse head to guide upon. After three nights' trial of this method, double wires were substituted for the single wires, and the nucleus was kept inside the square formed by their intersections. This kept the nucleus in sight all the time. The square was very little larger than the nucleus. This method required more careful watching than the other, as there were four intersections for the nucleus to hide behind instead of one; and when it disappeared some time was required to find it. So long as the nucleus was kept in sight within the square, this method gave better results than the other, as can be seen by comparing the star-trails on the photographs taken on July 25th and 27th with those taken later.

On July 25th, with an exposure of only $1^h\ 10^m$, the tail could be traced for about four degrees. It was very slender and straight, but so faint that less than half of it can be seen on the accompanying photograph. With an exposure of six minutes on the same night, the tail appeared to be only half a degree long. On the plate of July 26th the tail was but forty minutes long, and was very faint, except within fifteen minutes of the head. The long, slender parts seen on the night before had disappeared, although the exposure was of $1^h\ 37^m$ duration. On the same night Mr. CRAWFORD secured a photograph with the Crocker telescope with an exposure of about two hours, which showed the same short tail. That night the tail seemed to fork about twenty minutes from the head. The same phenomenon was noticed on July 27th, whereas the plates taken after that showed the tail to be fan-shaped, as though the space between the forks had been filled in. On July 29th and August 3d the tail was fan-shaped for only half its length, the outer half being straight and slender. In both cases this extension was very faint — too faint to show on any of the accompanying reproductions. The length of the tail varied irregularly, not being entirely dependent upon the length of the exposure, as is shown in the following table. In this the first column gives the date of the exposure, the second the length of the exposure, and the third the length of the tail.

PHOTOGRAPHS OF COMET II, 1900, (BORRELLY–BROOKS).

Date.	Exposure.	Length of Tail	Position-Angle. Tail.	Radius-Vector.	T—R.
July 25	$1^h 10^m$	4°	245°	253°	— 8°
25	6	30′	...	...	...
26	1 37	40	236	254	— 18
..	....	..	246	254	— 8
27	2 15	70	240	254	— 14
28	2 38	80	245	255	— 10
29	2 29	80	238	255	— 17
30	2 47	60	242	256	— 14
31	2 6	90	247	257	— 10
Aug. 1	3 10	60	244	257	— 13
2	3 2	40	250	258	— 8
3	3 9	120	250	258	— 8
4	57	30	...	...	...

The tail was so faint that if the air happened to be at all hazy the end of it would be obscured. This would hardly be sufficient to explain the difference between the lengths of the tail on August 2d and 3d.

On all the plates, except the second and last, the slide of the plate-holder was left out about two inches after the exposure, and the clock stopped, allowing the stars to trail on one end of the plate. The position-angle of the tail was then determined from the angle between these trails and the axis of the tail. The tail, in most cases, was so very short and ill-defined that the axis could not be determined with certainty, and consequently the position-angle was estimated to the nearest degree only. This quantity is given in column four of the table. Column five contains the computed position-angle of the radius-vector of the comet, and column six the difference between columns four and five, in the sense column four minus column five. Two values are given for the position angle of the tail on July 26th, one for each fork. The mean of the two values of T—R is 13°,—but little greater than the mean of the whole column, which is 11°.6. While these values of T—R appear to vary a great deal, it is not much more than it is to be expected, as an examination of the accompanying photographs will show how uncertain the position of the axis of the tail is. Greater extent of tail can be seen on the negatives, but it is so faint that the extension hardly adds to the accuracy. The values of T — R have a range of only ten degrees, and all show a decided negative value, larger than the probable error of the result; showing that the tail did not coincide with the radius-vector of the comet.

The whole head was so bright that even on the six-minute plate the nucleus has disappeared from over-exposure. An exposure of less than a minute would probably have been sufficient to show the nucleus alone.

A PRELIMINARY DETERMINATION OF THE MOTION OF THE SOLAR SYSTEM.*

By W. W. Campbell.

The first investigation undertaken with the Mills spectrograph, in May, 1895, related to the determination of the radial velocities in the system of *Saturn.*† It confirmed, in all respects, the noted results announced by Professor Keeler a few weeks earlier. Determinations of stellar velocities were now undertaken, and results of considerable accuracy were at once obtained. The observed velocities of a bright solar type star could be depended upon to fall within a range of five or six kilometers. However, it soon became apparent that the instrument contained many defects. Some of these, with their remedies, have been described in my article on "The Mills Spectrograph," in the *Journal* for October, 1898; but the large majority were purely local, and do not call for special comment. The greater part of the first year was devoted to isolating and eliminating these defects; and it was not until the summer of 1896 that results considered satisfactory for publication were secured. Added precautions taken, and improvements made in the instrument and methods, have shown corresponding and gratifying increase of accuracy from year to year.

Following the methods of observation already described in the *Journal*, two thousand spectrograms have been secured since the summer of 1896. These include: plates of the solar spectrum for determining the camera-focus and scale-values; plates of stellar spectra for determining the focus of the 36-inch objective at different temperatures; plates of comparison-spectra, etc.; perhaps one hundred stellar spectrograms rejected for cause, without measurement; and in the neighborhood of fifteen hundred satisfactory spectrograms of about three hundred and twenty-five stars, situated between the North Pole and Declination — 30°. At least three or four hundred of these photographs relate to spectroscopic binaries, for some of which, such as *ζ Geminorum*, nearly fifty plates were needed.

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* Reprinted from the *Astrophysical Journal* for January, 1901.

† *Astrophysical Journal*, August, 1895, pp. 127-135.

It is not practicable to publish the observed velocities at the present time, for two reasons:—

(*a*) Many of the plates have been only partially measured, and reduced by approximate methods. Experience shows that these approximate results may be changed as much as $1\frac{1}{2}^{km}$ by the final measures and reductions, though the average change is much less.

(*b*) The reductions have not been based upon the definitive wave-lengths of the solar and comparison lines. These are not yet available, but they are expected soon.

Repeated requests have been made that the observations already secured should be used to determine the motion of the solar system with reference to the system of observed stars; and it is the purpose of this article to communicate the preliminary results of such an investigation.

Omitting several Type I stars whose lines could not be accurately measured, and some thirty spectroscopic and visual * binaries for whose centers of gravity the velocities are not yet known, there remain 280 stars available for determining the relative motion of our system. Inasmuch as this number is constantly increasing with the progress of the observations, and in a few years will, I hope, be doubled, and include stars distributed over the entire sky, it did not seem necessary to form an equation of condition for each star. The 280 stars were divided into 80 groups, by combining neighboring stars into one group; taking the mean of their individual velocities as the velocity of the group. The data for each of the 80 groups are contained in the first four columns of Table I.

Let v be the observed speed of a star with reference to the solar system; V the Sun's speed with reference to the system of 280 observed stars; and D the angular distance of a star from the apex of the solar motion. Then each star, or each group of stars, furnishes an equation of condition having the form:—

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* Such as *Sirius*, *Procyon*, etc.

$$V \cos D - v = 0. \qquad (1)$$

Let α_0, δ_0 be the coordinates of the apex, and α, δ those of the star; then we have $\cos D$ defined by the well-known equation for the distance between two stars or points,

TABLE I.

No. of Stars.	Mean R. A.	Mean Dec.	Mean Observed Velocity.	No. of Stars.	Mean R. A.	Mean Dec.	Mean Observed Velocity.
	h m	°	k		h m	°	k
2	0 26.5	−14.0	+17.0	3	12 20.4	+43.0	− 4.7
6	0 40.0	+57.8	−10.3	3	12 35.7	−22.5	− 1.7
5	0 45.0	+28.2	−24.2	3	12 48.1	+ 4.9	−17.0
3	1 23.0	−10.1	+12.7	2	13 6.2	+23.2	− 8.2
4	1 35.5	+43.9	+ 0.2	2	14 9.2	− 7.6	+ 3.0
3	1 43.7	+10.6	+ 7.3	5	14 14.9	+18.1	− 3.9
2	1 47.4	−19.0	+ 2.5	2	14 29.5	−25.6	+11.8
2	2 2.6	+24.2	−19.0	7	14 58.0	+29.6	−13.1
9	2 38.5	−14.1	− 3.2	4	15 2.4	+46.0	−28.5
3	2 54.4	+ 0.1	+21.7	4	15 23.2	+ 4.8	− 7.0
5	2 55.4	+50.2	+13.6	4	15 27.4	+65.8	−14.2
4	3 3.8	+41.2	+ 4.5	4	15 41.4	−12.9	− 1.0
3	3 16.9	+13.6	+ 6.7	4	16 17.1	−20.8	−11.1
3	3 45.8	− 9.2	−10.7	4	16 32.8	− 8.5	− 7.0
3	4 3.2	−17.3	+34.8	3	16 38.0	+13.3	−26.0
5	4 16.6	+18.0	+35.5	3	16 49.5	+35.9	−29.0
2	4 29.7	+79.8	− 3.0	3	17 44.7	+53.6	−22.3
4	4 46.8	+44.7	+ 8.2	4	17 53.6	+29.5	− 9.9
3	5 15.7	+37.4	+30.7	3	17 53.8	+ 5.3	− 7.5
2	5 17.0	+ 7.1	+22.0	6	18 18.6	− 7.2	− 5.4
4	5 23.5	−20.9	+ 1.8	6	18 36.4	−23.5	−23.5
3	5 32.6	− 7.5	− 0.7	3	18 38.6	+19.0	−28.5
3	5 51.5	+57.7	+ 5.0	2	18 43.0	+41.2	−20.5
4	6 18.1	+25.0	+24.8	6	18 48.9	+69.6	+ 6.4
2	6 41.0	−15.6	+50.5	4	19 42.1	+ 6.2	−19.9
3	6 43.3	+16.7	+ 6.3	5	19 42.6	+23.6	−11.6
3	7 32.4	+27.0	+11.3	4	20 3.6	+55.4	−44.2
2	7 33.8	−25.1	+42.0	3	20 19.3	− 9.1	− 8.7
2	7 47.0	+ 9.3	+34.0	3	20 48.9	+43.3	+ 1.0
2	7 50.6	− 6.0	+21.0	5	20 58.5	+12.8	−28.2
4	8 56.6	+10.5	+26.9	5	21 1.3	+31.9	− 2.6
2	8 57.8	+32.0	+25.2	4	21 24.6	−15.8	− 2.9
4	8 58.0	+65.7	− 4.0	3	22 00.2	+12.7	− 7.3
2	9 10.2	+47.2	+19.0	2	22 13.6	+54.7	−14.2
3	9 27.2	− 3.7	+12.3	4	22 32.6	− 6.7	−11.3
2	9 57.2	+22.3	−15.2	5	22 52.9	+25.4	− 0.2
5	10 40.2	−15.2	+19.6	2	23 10.6	+71.4	−26.5
5	10 44.7	+38.1	− 2.8	4	23 10.7	−18.7	+ 5.6
2	11 11.6	+66.1	± 0.0	2	23 16.0	+43.8	− 2.0
6	11 32.8	+ 6.2	+ 3.7	4	23 31.0	+ 5.0	− 0.9

$$\cos D = \sin \delta_0 \sin \delta + \cos \delta_0 \cos \delta \cos (\alpha_0 - \alpha). \qquad (2)$$

If we place

$$\left.\begin{aligned} x &= V \sin \delta_0 \\ y &= V \cos \alpha_0 \cos \delta_0 \\ z &= V \sin \alpha_0 \cos \delta_0 \end{aligned}\right\} \qquad (3)$$

equations (1) take the form

$$\sin \delta \,.\, x + \cos \alpha \cos \delta \,.\, y + \sin \alpha \cos \delta \,.\, z - v = 0 \qquad (4)$$

from which the values of x, y, and z may be determined; and the values of V, α_0, and δ_0 may then be found from (3) by the relations

$$\left.\begin{aligned} V^2 &= x^2 + y^2 + z^2 \\ \tan \alpha_0 &= \frac{z}{y} \\ \sin \delta_0 &= \frac{x}{V} \end{aligned}\right\} \qquad (5)$$

The values of α and δ for each group were substituted in equation (4), and the resulting equation was weighted in proportion to the number of stars on which it is based, as indicated in column one of the table. The eighty equations thus formed were combined and solved by the method of least squares, and the following elements of the solar motion were obtained:—

$$\begin{aligned} V &= - \;\; 19.89^{km} \pm 1.52^{km} \\ \alpha_0 &= \;\; 277^\circ\, 30' \;\; \pm 4^\circ.8 \\ \delta_0 &= + \;\; 19^\circ\, 58' \;\; \pm 5^\circ.9 \end{aligned}$$

The list of stars employed in this investigation includes all that were available; none were rejected arbitrarily, on account of very high speed or otherwise. The results represent the solar motion relative to the entire system of observed stars. Had a dozen stars of great velocity been rejected, the speed and direction of the motion would have been only slightly different, but the computed probable errors would have been very much smaller than those appended.

On the basis of these elements, the component correction for the solar motion was computed and applied to each star. The 280 results obtained in this manner represent the individual stellar components of motion in the line of sight, with reference to the entire system. Of these there are

		Km per second.
151	positive, average,	+17.01
129	negative, average,	—17.10
280	numerical average,	17.05

The average component velocity of each star in a plane at right angles to the line of sight is therefore

$$\frac{\pi}{2} \cdot 17.05 = 26.78^{\rm km} \text{ per second;}$$

and the average velocity *in space* of each star in the system is

$$2 \times 17.05 = 34.10^{\rm km} \text{ per second.}$$

The Sun's relative velocity, $19.9^{\rm km}$, is therefore much smaller than that of the average star of the system, $34.1^{\rm km}$.

The 280 stars were classified roughly, according to their spectral types, in the following manner: the *Harvard Photometry* contains estimates of their brightness, based upon the visual radiations. The *Draper Catalogue* estimates their brightness by virtue of the photographic intensities of their spectra in the $H\gamma$ region. The difference between the visual and photographic magnitudes is very small in the case of the white stars, such as *β Orionis;* it is usually from 1.5 to 2.0 magnitudes for the solar type stars, such as *β* and *γ Andromedæ;* and is fully 2.5 magnitudes for red stars, such as *α Scorpii.*

In the system of stars observed, the difference of magnitude is equal to or greater than 1.0 for 144 stars. Subdividing these according as their component velocities in the line of sight are positive or negative, we have

78 positive, average component,	$+ 17.07^{\rm km}$
66 negative, average component,	$- 14.99$
144 numerical average, ...	16.12

For 136 stars the difference of magnitude is less than 1.0, as follows:—

73 positive, average component,	$+ 16.94^{\rm km}$
63 negative, average component,	$- 19.32$
136 numerical average, ...	18.04

The discrepancy of $1.9^{\rm km}$ in the results is hardly sufficient to justify any statement as to the effect of spectral type upon velocity.

The relations between visual brightness and velocity was next investigated.

Of stars equal to or brighter than 3.0 magnitude, there are

26 positive, average component,	$+ 13.11^{\rm km}$
21 negative, average component,	$- 12.99$
47 numerical average, ...	13.05
Corresponding velocity in space,	26.10

Of stars lying between magnitudes 3.1 and 4.0 inclusive, there are

59	positive, average component,	+ 17.70^{km}
53	negative, average component,	— 14.42
112	numerical average, ...	16.15
	Corresponding velocity in space, .	32.30

Of stars fainter than 4.0 magnitude, there are

66	positive, average component,	+ 17.93^{km}
55	negative, average component,	— 21.27
121	numerical average, ...	19.44
	Corresponding velocity in space, .	38.88

The progression in these results is so pronounced, and the differences are so large, that I think we are justified in drawing the important conclusion that the faint stars of the system are moving more rapidly than the bright stars. This apparent fact, derived quite independently of any assumption as to the relative distances of the stars of different magnitudes, should profoundly affect the question of and the methods of determining the structure of our sidereal system. If the fainter stars are moving relatively more rapidly than has been previously assumed, they must be relatively farther from us than the investigations of their proper motions have led us to conclude.

This progression is in no wise due to an increase of probable error of a velocity determination with decreasing magnitude. The probable error of a single determination is well under half a kilometer for such excellent stars as *Polaris* and *Procyon;* and it is not much greater for fifth-magnitude stars whose spectra contain well-defined lines.

The elements of the solar motion deduced above depend upon the assumption that their most probable values are those which make the sum of the squares of the residual stellar components of speed in the line of sight a minimum. This, in turn, assumes that the magnitudes of these components are distributed according to the law of accidental errors. No doubt they are distributed according to a somewhat different law, which I hope to investigate fully a few years later, before making a definitive determination of the motion, based upon a much larger number of stars distributed over the entire sphere.*

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* An additional reason for delay arises from the fact that many years of observation are required to establish constancy of stellar velocities, in some cases; of the stars used in the above determination, two have since been discovered to have variable velocities.

The Right Ascension of the apex, 277° 30′, agrees exactly with the value deduced by Professor NEWCOMB[*] from all the "proper motion" data available; and differs only 1° 30′ from Professor KAPTEYN'S[†] assumed value, 276°. My value of the Declination + 19° 58′, differs widely from NEWCOMB'S value, + 35°, and KAPTEYN'S, + 34°. It must be noticed that very few radial velocities are available for the region — 15° to — 30°, and none whatever south of — 30° Declination. Fully one third of the sky is unrepresented in the solution. The data for determining the Declination of the apex are extremely unsymmetrical in arrangement. The data north of the line of motion are fairly complete, whereas the data to the south are very incomplete. To determine the Declination therefrom is somewhat similar to flying with one wing very imperfect. The Right Ascension, on the contrary, is determined from data reasonably symmetrical in distribution.

A comparison of my results with those obtained by STUMPE[‡] from proper motions is of great interest. He classified the stars of relatively large proper motions according to their visual magnitudes, with the following results for the position of the apex:

No. of Stars.	Magnitude.	R. A.	Dec.
284 . . .	1 to 5.5	263°.8	+ 31°.1
473 . . .	5.6 to 7.5	290. 7	+ 37. 5
238 . . .	7.6 to >	286. 7	+ 46. 9

In view of these widely different positions of the apex, it is perhaps not surprising that my result for Declination, depending upon even brighter stars than his first group should be smaller than any hitherto obtained.

The motion of the solar system is a purely relative quantity. It refers to specified groups of stars. The results for various groups may differ widely, and all be correct. It would be easy to select a group of stars with reference to which the solar motion would be reversed 180° from the values assigned above. It is perhaps unsafe to draw conclusions, from my value of the Declination, concerning the drift of the brighter (and presumably nearer) stars until the data from the southern sky are available.

Before making the preceding solution for the solar motion by the method of least squares, I had already made an approximate determination of the speed of the solar system, by a different method, as follows: the apical distance D of each star was computed from NEWCOMB's assumed coordinates of that point ($\alpha = 277^\circ.5$; $\delta = +35^\circ$). The stars were formed into groups according to their apical distances, as indicated in the first column of Table II. The number of stars in each group is given in column two. The mean apical distance of the group is $[D]$ and the mean observed velocity is $[v]$. It is interesting to note that each $[v]$ between apical distances 0° and 90° is negative, and each one between 90° and 180° is positive. Each radial velocity furnishes an equation of condition of the form

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[*] *Astronomical Journal*, No. 457, pp. 4, 5.

[‡] *Astronomical Journal*, No, 457, p. 5.

[†] *Astronomische Nachrichten*, No. 3487, p. 104.

$$V - v \sec D = 0, \tag{6}$$

from which to determine V. We shall assume that the weight of each determination is equal to cos D. The resulting value of V will now be given by

$$V = \frac{\Sigma\,(n \cos [D] . [v] \sec [D])}{\Sigma\, n \cos [D]} = \frac{\Sigma\, n\, [v]}{\Sigma\, n \cos [D]} . \tag{7}$$

Substituting the values of n, $[v]$, and $[D]$ in this equation, I obtained

$$V = -\,20.4^{\mathrm{km}}.$$

TABLE II.

Apical distances.	n	$[D]$	$[v]$	cos $[D]$
0°— 10°	4	7°.4	− 9.9	+0.992
10 — 20	10	15.5	−24.0	+ .964
20 — 30	16	24.7	−17.5	+ .908
30 — 40	24	34.8	−12.9	+ .821
40 — 50	24	44.1	−16.6	+ .718
50 — 60	29	54.6	− 6.1	+ .579
60 — 70	29	64.4	− 7.0	+ .432
70 — 90	47	79.7	− 2.7	+ .179
90 —110	35	99.4	+ 8.0	− .163
110 —120	19	116.3	+14.4	− .443
120 —130	18	124.4	+13.8	− .565
130 —140	10	134.4	+16.4	− .700
140 —150	5	145.1	+14.6	− .820
150 —160	6	156.0	+29.3	− .914
160 —170	4	164.0	+ 6.0	−0.961
	280			

$$V = \frac{\Sigma\, n\, [v]}{\Sigma\, n \cos [D]} = \frac{-3010}{147.5} = -\,20.4^{\mathrm{km}}.$$

If we use this value of V as a basis for further approximations to its true value, by the method of KAPTEYN,* we shall obtain $V = -19$ kilometers; though it should be said that this method involves assumptions concerning proper motions.

The foregoing data bear decisively upon the question of stellar parallaxes and other fundamental problems; but these portions of the subject are reserved for a future paper.

The work with the Mills spectrograph has furnished many important by-products. Special mention may be made of the discovery of an unexpectedly great number of spectroscopic binaries. Two or more satisfactory observations have been secured for each of 285 stars of my programme. From the Mills spectrograph observations alone we have discovered that thirty-one † of these stars are spectroscopic binaries. To these we must add three binaries in the same list previously discovered by another observer, ‡ making thirty-four in all. That is, of 285 observed stars, *more than one star in nine is a spectroscopic binary.* Further, five additional suspected binaries await verification, and it is altogether probable that many other stars in the list are binaries awaiting discovery. Two plates are not sufficient to detect variable velocity, even in many cases of short period; and still less are they sufficient in many cases of long period, now coming to light by virtue of our older observations. It is not improbable that at least one star in five or six will be found to be a spectroscopic binary; and I should not be surprised to see a still larger ratio established.

The proven existence of so large a number of stellar systems differing widely in structure from the solar system gives rise to a suspicion, at least, that our system is not of the prevailing type of stellar systems. The new field of astronomical research thus opened up is of great richness, and may well occupy the attention, for an indefinite period, of the large number of observers and institutions now engaging in its development. It is perhaps unnecessary to say that the measure of success attainable is dependent upon the degree of accuracy * realized in the observed velocities.

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* *Astronomische Nachrichten*, No. 3487.

† Twenty-five of these have been announced in the *Journal*, and six now await announcement.

‡ Dr. BĚLOPOLSKY, at Pulkowa, α_1 *Geminorum*; the well-known variable stars δ *Cephei* and η *Aquilæ*; and the independent and prior discovery of the binary character of the well-known variable, ζ *Geminorum*.

It is a pleasure to record that I have been assisted most efficiently in these investigations, since August, 1897, by Mr. W. H. WRIGHT, assistant astronomer.

LICK OBSERVATORY,
UNIVERSITY OF CALIFORNIA, December, 1900.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1901.

BY MALCOLM MCNEILL.

MAY.

There will be a very close approximation to a lunar eclipse at Full Moon on May 3d, the Moon passing within 1′ of the Earth's shadow. At the succeeding New Moon, May 17th, there will be a total eclipse of the Sun. The line of totality lies in the southern hemisphere, and passes almost wholly through the ocean, but crosses the islands of Sumatra, Borneo, and New Guinea. The eclipse is remarkable on account of the great duration of totality, nearly six and one half minutes in some places, a duration four times as great as any available duration for the eclipse of May 28, 1900.

Mercury is a morning star at the beginning of the month, but passes superior conjunction on May 14th, and becomes an evening star. It moves rapidly away from the Sun, eastward and northward. Toward the end of the month it becomes a comparatively easy object in the evening twilight, not setting until an hour and a half after sunset.

Venus is now an evening star, having passed superior conjunction with the Sun on April 30th, but remains quite close to the Sun throughout the month. At the end of the month it sets only a little more than half an hour after sunset, and will be very hard to see.

Mars is still waning, increasing its distance from us 24,000,000 of miles during the month, and diminishing in brightness about one half. It moves about 10° east and 5° south during the month through the constellation *Leo*. On May 4th it passes between *Regulus* and η *Leonis* in the handle of the Sickle, not quite 2° north of the first. On May 31st it occupies a position about 3° south of the position it held on February 12th.

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* In the later observations of the *best stars* with the Mills spectrograph, an extreme range of two kilometers would afford strong suspicion of variable velocity; and the greater portion of a smaller range due to unavoidable errors would arise not from errors in the spectrograms, I believe, but from changes in the observer's personal habits of measuring the plates.

Jupiter and *Saturn* are now coming nearer to being evening stars, both rising before 10 P.M. toward the close of the month. Both are still in the constellation *Sagittarius*, and both are retrograding, *Jupiter* a little faster, on account of its lesser distance from us. At the close of the month their distance apart is about 4°, half a degree greater than it was at the beginning of the month.

Uranus rises earlier by about two hours, and has nearly come to opposition. It is retrograding in the southern extension of *Ophiuchus*.

Neptune sets shortly after sunset, and is getting into poor position for observation.

JUNE.

The Sun reaches the solstice and summer begins on June 21st, 7 P.M., Pacific time.

June affords the best time of the present year for observations of *Mercury*. The planet is an evening star throughout the month, and until the very last days sets more than an hour and one half after sunset. It comes to greatest east elongation on June 15th. This elongation is nearly 25°, more than 6° greater than the preceding greatest east elongation in February.

Mercury is in conjunction with *Venus*, about 4° south, on the evening of June 30th.

Venus is an evening star, rather farther from the Sun than it was in May. After the middle of the month it sets more than an hour after sunset, and will be an easy object to see.

Mars is to be found farther to the west in the evenings, and sets shortly after 11 P.M. by the end of the month. It still keeps up its rapid recession from the Earth, losing more than 20,000,000 miles and more than one third in brightness during the month. It is in the constellation *Leo*, and moves 13° east and 6° south, nearly to *Virgo*. On June 12th it reaches the point at which it began its retrograde motion in January, except that it is now about 3° south of its former position.

Jupiter and *Saturn* are still near together, although separating slightly. By the end of the month they rise about midnight.

They are still in *Sagittarius*, both moving eastward, *Jupiter* 4° and *Saturn* 2°, during the month, and at the end of the month *Jupiter* is about 6° west of *Saturn*. After their retrograde motion ceases, *Jupiter* will again approach *Saturn*, and they will come into conjunction with each other late in November. *Jupiter* is in opposition with the Sun, and consequently above the horizon during the entire time the Sun is below, on June 30th. The opposition of *Saturn* comes five days later.

Uranus is in opposition on June 5th. It retrogrades a little more than 1° in *Ophiuchus*, and at the close of the month is about 30′ north of the sixth-magnitude star *24 Ophiuchi*.

Neptune is in conjunction with the Sun on June 20th, and changes from evening to morning star.

MAY–JUNE, 1901.

PHASES OF THE MOON, P. S. T.

Full Moon . . .	May 3,	10^h 19^m	A. M.
Last Quarter . . .	May 11,	6 38	
New Moon . . .	May 17,	9 38	P. M.
First Quarter . . .	May 24,	9 40	
Full Moon . . .	June 2,	1 53	A. M.
Last Quarter . . .	June 9,	2 0	P. M.
New Moon . . .	June 16,	5 33	A. M.
First Quarter . . .	June 23,	12 59	P. M.

THE SUN.

1901.	R. A.	Declination.	Rises.	Transits.	Sets.
May 1,	2^h 32^m	+ 14° 57′	5^h 5^m A.M.	11^h 57^m A.M.	6^h 49^m P.M.
11,	3 11	+ 17 46	4 54	11 56	6 58
21,	3 50	+ 20 6	4 45	11 56	7 7
31,	4 31	+ 21 51	4 39	11 58	7 17
June 10,	5 12	+ 22 59	4 36	11 59	7 22
20,	5 53	+ 23 26	4 36	12 1 P. M.	7 26
30,	6 35	+ 23 13	4 39	12 3	7 27

MERCURY.

May 1,	1 39	+ 8 18	4 36 A.M.	11 4 A.M.	5 32 P.M.
11,	2 55	+ 16 19	4 44	11 41	6 38
21,	4 24	+ 22 54	5 7	12 30 P. M.	7 53
31,	5 49	+ 25 34	5 41	1 16	8 51
June 10,	6 55	+ 24 35	6 13	1 43	9 13
20,	7 37	+ 21 41	6 27	1 45	9 3
30,	7 50	+ 18 40	6 17	1 18	8 19

VENUS.

1901.		R. A.	Declination.	Rises.	Transits.	Sets.
May	1,	2 33	+14 12	5 10 A.M.	11 59 A. M.	6 48 P. M.
	11,	3 22	+18 3	5 5	12 8 P. M.	7 11
	21,	4 13	+21 6	5 4	12 19	7 34
	31,	5 5	+23 11	5 8	12 32	7 56
June	10,	5 59	+24 9	5 18	12 46	8 14
	20,	6 52	+23 57	5 32	1 0	8 28
	30,	7 45	+22 34	5 53	1 14	8 35

MARS.

May	1,	10 0	+14 28	12 34 P.M.	7 24 P.M.	2 14 A.M.
	11,	10 11	+13 7	12 11	6 56	1 41
	21,	10 25	+11 32	11 50 A.M.	6 30	1 10
	31,	10 40	+ 9 45	11 33	6 6	12 39
June	10,	10 57	+ 7 48	11 18	5 44	12 10
	20,	11 15	+ 5 42	11 4	5 23	11 42 P. M.
	30,	11 34	+ 3 28	10 51	5 2	11 13

JUPITER.

May	1,	18 57	−22 39	11 44 P.M.	4 23 A.M.	9 2 A.M.
June	1,	18 50	−22 51	9 37	2 15	6 53
July	1,	18 35	−23 10	7 26	12 2	4 38

SATURN.

May	1,	19 11	−21 55	11 56 P.M.	4 37 A.M.	9 18 A.M.
June	1,	19 7	−22 3	9 50	2 31	7 12
July	1,	18 58	−22 18	7 45	12 25	5 5

URANUS.

May	1,	17 0	−22 45	9 48 P.M.	2 26 A.M.	7 4 A.M.
June	1,	16 55	−22 38	7 42	12 20	4 58
July	1,	16 50	−22 30	5 35	10 14 P.M.	2 53

NEPTUNE.

May	1,	5 48	+22 15	7 53 A.M.	3 13 P.M.	10 33 P.M.
June	1,	5 53	+22 17	5 55	1 15	8 35
July	1,	5 57	+22 18	3 52	11 22 A.M.	6 42

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope.)

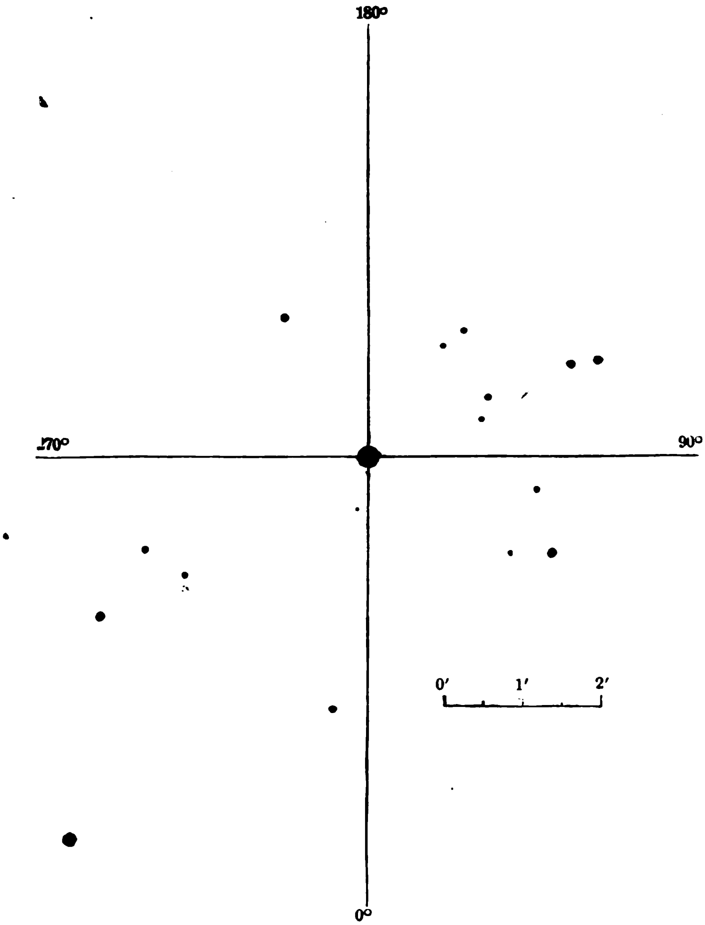
I, D, May	4,	1^h	46^m	A.M.	I, D, June	3,	3^h	50^m	A.M.
II, D,	6,	9	54	P.M.	I, D,	4,	10	19	P.M.
III, D,	10,	9	51		II, D,	7,	9	27	
III, R,	11,	12	37	A.M.	I, D,	12,	12	13	A.M.
I, D,	11,	3	40		I, D,	13,	6	41	P.M.
I, D,	12,	10	9	P.M.	II, D,	15,	12	2	A.M.
II, D,	14,	12	28	A.M.	I, D,	19,	2	7	
III, D,	18,	1	49		I, D,	20,	8	36	P.M.
III, R,	18,	4	36		II, D,	22,	2	37	A.M.
I, D,	20,	12	2		III, D,	22,	9	42	P.M.
II, D,	21,	3	2		I, D,	26,	4	1	A.M.
I, D,	27,	1	56		I, D,	27,	10	30	P.M.
I, D,	28,	8	25	P.M.	III, R,	30,	4	35	A.M.
II, D,	31,	6	53						

(FORTIETH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to M. MICHEL GIACOBINI, of the Nice Observatory, for his discovery of an unexpected comet on December 20, 1900.

The Committee on the Comet-Medal,

W. W. CAMPBELL,
W. M. PIERSON,
CHAS. BURCKHALTER.



NOVA PERSEI AND THE FAINT STARS NEAR IT.

NOTICES FROM THE LICK OBSERVATORY.[*]

PREPARED BY MEMBERS OF THE STAFF.

NOVA PERSEI.

The discovery of a new star in the constellation *Perseus*, by Dr. T. D. ANDERSON, a private astronomer of Edinburgh, on the morning of February 22d, is one of the most interesting astronomical events of recent times. The discovery was announced by Professor COPELAND, Astronomer Royal for Scotland, with the following statement:—

"The great new star was discovered by Dr. T. D. ANDERSON, of this city, at 2:40 A.M. on Friday, 22d inst. At that time it was of the 2.7 magnitude, or fully half a magnitude fainter than the Pole Star, and shone with a bluish white light. Dr. ANDERSON himself kindly brought the news of this important discovery to the observatory in the forenoon, and marked off the exact position of the *Nova* on the map in ARGELANDER's great atlas of the northern heavens. Dr. ANDERSON's reputation as the discoverer of *Nova Aurigæ* in 1892, and of more than a score of telescopic variable stars, placed the reality of this new discovery beyond all doubt; so telegrams were at once dispatched to Greenwich and to Kiel for distribution to the observatories of the world.

"Evening had scarcely closed in when the *Nova* could be seen with the naked eye, even through light drifting clouds. To my eye it appeared to be of the first magnitude, being slightly brighter than *Aldebaran*. On examining its spectrum, we were astonished to find it almost absolutely continuous, and it was only after some time that Dr. HALM detected a number of delicate dark (Fraunhofer) lines, which I was able to confirm. Unfortunately, the sky clouded over before further critical observations could be made. Mr. HEATH was so fortunate as to secure a photograph of the new star at a time when all the neighboring stars were obscured by thick haze. The night of the 23d was very cloudy, and spectroscopic observations were impossible; but when, through a break in the clouds about 8 P.M., Dr. HALM and Mr. CLARK saw the star, they clearly made it out to be brighter than *Capella*, in fact to be the brightest star north of the celestial equator.

"A new special feature of this, the most considerable new star of modern times, is its enormous increase in brightness since its discovery,

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[*] Lick Astronomical Department of the University of California.

while all other new stars seem to have been discovered when at their greatest brilliancy, from which they rapidly declined.

"Dr. ANDERSON's place of the *Nova* for 1901 is: Right Ascension, $3^h\ 24^m\ 25^s$; North Declination, 43° 34′, or a little following the center of the line joining the stars *Beta* and *Delta*, in the constellation of *Perseus*."

It may be said that the resources of nearly all the active observatories were at once devoted to the study of the wonderful stranger, in so far as they promised to yield useful results.

A fact of great interest was promptly announced by Professor E. C. PICKERING, Director of Harvard College Observatory. Photographs of this region of the sky had been secured, in the course of their regular surveys, on February 2d, 6th, 8th, 18th, and 19th, none of which recorded a star in the position of the *Nova*, though the last plate contained images of 11th-magnitude stars. The *Nova* thus increased from fainter than 11th magnitude to the 2.7 magnitude in less than three days; and on the 24th had become the brightest star in the northern hemisphere.

The first opportunity for securing observations at Mt. Hamilton occurred on the forenoon of February 24th. There was no difficulty in finding it with the 12-inch telescope, in broad daylight. Comparison of the brightness of the *Nova* with that of *Capella* showed that the former was half a magnitude the brighter.

The position of *Nova Persei* was determined from meridian-circle observations by Professor TUCKER on eight consecutive nights, from February 24th to March 3d, to be

$$\begin{aligned}\text{Right Ascension} &= 3^h\ 24^m\ 28^s.086\\ \text{Declination} &= 43^\circ\ 33'\ 54''.03\end{aligned}$$

referred to the mean equinox of 1901.0. Readers will have no difficulty in locating the *Nova*, by means of these coordinates, in their star-charts.

The position of the *Nova* with reference to a number of neighboring faint stars has been accurately determined by Mr. AITKEN, using the micrometer of the 36-inch refractor.

Mr. PALMER has secured photographs of *Nova Persei* and the surrounding stars, and has measured its position with reference to four catalogue stars on the plates.

The brightness of the star has been estimated on every clear night by Messrs. TUCKER and AITKEN. It has diminished from zero magnitude, on February 24th, to the fourth magnitude and fainter, the latter part of March, in an irregular manner.

Our two single-prism spectrographs having just been shipped to Sumatra, the spectroscopic observations on February 24th were made with the Mills spectrograph. On the 25th and succeeding nights efficient one-prism instruments were available. Those fortunate enough to secure observations on the 22d and 23d reported that the spectrum was practically continuous, traversed by dark lines, on those dates. Observations secured here and elsewhere on the 24th and later showed that the spectrum was rapidly approaching the type of new-star spectrum exemplified by *Nova Aurigæ*, discovered by Dr. ANDERSON in 1892; and by *Nova Normæ* (1893), *Nova Carinæ* (1895), *Nova Sagittarii* (1898), and *Nova Aquilæ* (1899), discovered by Mrs. FLEMING on the Draper Memorial Photographs. Some minor points of difference exist; but the general features are the same, leaving no doubt that all these new stars exemplify the same class of phenomena.

The bright bands which were very prominent in *Nova Aurigæ* are present, with greater width, in *Nova Persei*. The stronger bands have, similarly, dark bands on their violet edges. The contrasts between bright and dark bands are weaker in the present star than in that of 1892.

It was noticed on the 25th of February that the D_1 and D_2 lines of sodium are present as narrow dark lines within the broad bright D band. A little later the fine dark H and K lines were found in the broad bright calcium bands. These were utilized at once for determining the velocity of *Nova Persei* in the line of sight. Observations from February 25th to March 18th yielded fairly consistent values of 6 kilometers per second recession from the solar system, depending upon the sodium and calcium lines.

A large number of beautiful spectrum plates have been secured, which Mr. WRIGHT is engaged in measuring and reducing preparatory to their publication in detail.

The cause of this star's sudden appearance is unknown. It undoubtedly existed previously as a dark and invisible star, or stars, in its present position. Some astronomers are inclined to hold to the view that we are dealing with two bodies traveling through space with an enormous relative velocity; but it seems to me that the substantial agreement of the features of the last half-dozen new-star spectra is practically conclusive evidence against this theory; and the work of WILSING shows that such an hypothesis is unnecessary. Likewise, the theory that the phenomena are caused by a dark body rushing violently through a nebulous cloud seems to be too special to fit a uniform class of phenomena. Whether a stupendous volcanic outburst from one star, whatever its cause, or the collision of two dark bodies, could supply the observed facts, remains in doubt. The spectrum contains sufficient proof that the atmosphere of the star is disturbed in the extreme. W. W. CAMPBELL.

March 31, 1901.

NOVA PERSEI AND THE FAINT STARS NEAR IT.

The following measures were made for the purpose of locating the faint stars that are visible in the telescope close to the new star discovered by ANDERSON. All the stars that could be seen with the 36-inch telescope within 3′ of the *Nova* were measured, as well as a few that are more distant. As all of these stars are quite faint, the new star was also connected with the 9.0-magnitude star (Bonn A. G. Catal., 2948), which is about 6′ north of and preceding it.

The observing conditions on all the nights available for these measures were not very favorable, and the measures of distance were nearly all difficult. This was especially the case with the nearest star (*a*), which was at the limit of vision. The estimates of magnitude must be considered as relative rather than absolute. In addition to the estimates made on the nights of the measures, the following comparative estimate was made on March 29th: $o = 12.5$; $k = i = f = 13.0$; $l = m = 13\frac{1}{4}$; $j = c = 13.5$; $g = h = n = 14.0$; $b = 14\frac{3}{4}$: $e = 15.5$; $d = 16.0$; *a*, not visible.

The diagram facing page 65 shows the relative positions of these stars.

Nova and *a*.

Date.	Angle.	Distance.	Magnitude.
1901.184	348°.0	39″.39	—16.5
.203	348 .7	40 28	—16 5
1901.19	348°.4	39″.82	—16.5
	b.		
1901.184	107°.9	90″.86	—14.5
.239	108 .1	91 .88	—14.5
1901.21	108°.0	91″.37	—14.5

c.

1901.159	117°.2	102″.31	—13.5
.184	116 .6	102 .30	—13.5
.239	116 .7	103 .33	—13.5
1901.19	116°.8	102″.65	—13.5

e.

1901.203	142°.7	121″.34	—15.5

f.

1901.159	211°.4	123″.96	—13.0
.184	210 .9	125 .13	—13.0
.239	210 .9	124 .76	—13.0
1901.19	211°.1	124″.62	—13.0

i.

1901.159	62°.8	158″.33	—13.0
.184	63 .2	158 .21	—12.5
.203	63 .3	157 .95	—13.5
1901.18	63°.1	158″.16	—13.0

k.

1901.203	114°.6	168″.86	—13.0
.239	114 .5	170 .64	—13.5
1901.22	114°.5	169″.75	—13.2

n.

1901.184	352°.0	192″.75	—13.5
.239	352 .3	193 .39	14.0
1901.21	352°.2	193″.07	13.8

o.

1901.159	300°.3	236″.35	—13.0
.184	300 .4	236 .63	—12.0
1901.17	300°.4	236″.49	—12.5

p (= Bonn A.G. 2948).

1901.176	321°.6	367″.73	—9.0
.184	321 .7	367 .45	—9.0
1901.18	321°.6	367″.59	—9.0

e and *d.*

1901.203	306°.7	19″.50	—16.0

i and *g.*

1901.203	270°.4	30″.91	—13.5
.239	269 .6	31 .34	14.5
1901.22	270°.0	31″.12	—14.0

i and *h*.

1900.203	194°.5	45″.42	—13.5
.239	195 .4	45 .97	—14.0
1901.22	195°.0	45″.70	—13.8

o and *j*.

1901.159	114°.9	71″ 71	—13.0
.184	114 .7	72 .78	—14.0
.239	114 .5	71 .85	—13.5
1901.19	114°.7	72″.11	—13.5

o and *l*.

1901.159	144°.2	61″.39	—13.5
.184	144 .2	61 .68	—13 0
.239	144 .3	61 .99	—13.0
1901.19	144°.2	61″.69	—13.2

k and *m*.

1901.203	100°.4	21″.39	—13.5
.239	100 .2	22 .01	—13.0
1901.22	100°.3	21″.70	—13.2

R. G. Aitken.

THE VELOCITY OF GROOMBRIDGE 1830 IN THE LINE OF SIGHT.

The star No. 1830 in Groombridge's catalogue has been called the "Runaway Star," on account of its large proper motion. Its position in the heavens is changing at the rate of 7″.05 per year,—a speed sufficient to carry it over one degree in five hundred years. This was the maximum stellar motion known up to the year 1898, at which date an 8th-magnitude star in the southern hemisphere was found to have a proper motion of 8″.7 per annum.

Several determinations of the parallax of Groombridge 1830 have been made. The separate results differ widely in value, but they are in substantial agreement in placing the star at a great distance; it is probable that at least twenty stars with large proper motions are nearer than Gr. 1830. From a consideration of the merits of the individual determinations, Newcomb has adopted 0″.14 as its most probable parallax. Assuming this to be its true value, the component of the star's velocity at right angles to the line of sight is 240 kilometers (150 miles) per second. This is by far the largest cross-motion assigned for any of the stars whose parallaxes have been measured.

Inasmuch as the proper motion, both in arc and in linear measure, takes account of the component of motion at right angles to the line of sight, it is of unusual interest to have a determination of the component of speed in the line of sight. This determination has been made with the Mills spectrograph, after replacing its three dense prisms by one light prism.

Four spectrum photographs have been secured in the past two months, of which two are very satisfactory, and one is excellent. The results given by the four are in substantial agreement; those given by the best two are — 93 and — 97 kilometers (58 and 60 miles approach) per second, respectively. Their mean value, -95^{km}, is possibly uncertain to the extent of five kilometers.

In view of the very great uncertainty existing in the value of the parallax, no interest attaches to the value of the angle resulting for the direction of the star's motion in space.

Gr. 1830 is of the 6.5 visual magnitude. The photographic magnitude on the Draper Catalogue standard, must be in the vicinity of 7.5, though this catalogue assigns it as 6.63. The spectrum is approximately of the solar type, though it may incline strongly toward the characteristics of *Procyon* or *α Persei.*

The best photograph was secured with an exposure of two hours, in average seeing, using slit-width $0^{mm}.032$. The measurable lines on the plate are between λλ 4000 - 4415. The region λ 4415 - Hβ is over-exposed. The spectrum is about 0′.25 in width. The light flint prism gives about two ninths as much dispersion as the three Mills prisms.

The greatest interest of the observations lies in the fact that fairly accurate determinations of stellar velocities are shown to be possible down to the eighth or ninth photographic magnitudes, provided their spectra contain well-defined lines.

W. W. CAMPBELL.

COMET NOTES.

Professor KREUTZ has computed elliptic elements for Comet *c* 1900 (GIACOBINI) which show that it is a member of the same group to which Comet Wolf and Comet Barnard belong. The periodic time is a little less than seven years. Long-continued cloudy weather during January and February made it impossible to follow this object as closely as was desirable. Observations were secured with the 12-inch on January 13th and 15th, and with the 36-inch on February 15th. The observed places are in good agreement with those computed from the elliptic elements.

On February 15th the comet was a very difficult object to measure, even with the great refractor, and on March 8th it could not be seen at all, though the conditions were good.

Comet Brorsen, which was expected to return to perihelion in January, was looked for with the 36-inch telescope on several mornings in February, but without success. The atmospheric conditions during the search were good, and a field about two degrees square was examined on each night.

R. G. AITKEN.

SOME STARS WITH LARGE RADIAL VELOCITIES.

While pursuing the regular programme of observation with the Mills spectrograph, it was found that the following stars have large velocities in the line of sight, as indicated below:—

ϵ *Andromedæ* ($\alpha = 0^h\ 33^m;\ \delta = +\ 28^\circ\ 46'$).

1898, October 4	$-\ 83.4^{km}$	WRIGHT.
October 9	$-\ 83.3$	WRIGHT.
1899, August 29	$-\ 84.6$	WRIGHT.
1900, August 22	$-\ 83.4$	WRIGHT.
Mean,	$-\ 83.7$	

μ *Cassiopeiæ* ($\alpha = 1^h\ 0^m;\ \delta = +\ 54^\circ\ 20'$).

1900, September 9	$-\ 97.2^{km}$	WRIGHT.
September 18	$-\ 97.0$	WRIGHT.
December 11	$-\ 98.$	CAMPBELL.

The proper motion of μ *Cassiopeiæ* is $3''.75$ per year. JACOBY's parallax, determined from the Rutherford photographs, is $0''.275$. These correspond to a motion at right angles to the line of sight of 66^{km} per second, though this includes nearly the full component of the motion of the solar system.

δ *Leporis* ($\alpha = 5^h\ 47^m.0;\ \delta = -\ 20^\circ\ 54'$).

1900, December 24	$+\ 95^{km}$	CAMPBELL.
December 25	$+\ 96$	CAMPBELL.
December 30	$+\ 94$	CAMPBELL.

θ *Canis Majoris* ($\alpha = 6^h\ 50^m$; $\delta = -\ 11°\ 55'$).

1897, December	15	$+\ 96^{km}$	CAMPBELL.
1899, October	16	$+\ 96.0$	WRIGHT.
1900, October	9	$+\ 95.5$	WRIGHT.

I *Pegasi* ($\alpha = 21^h\ 17^m$; $\delta = +\ 19°\ 23'$).

1900, July	3	$-\ 75.7^{km}$	WRIGHT.
July	8	$-\ 74.9$	WRIGHT.
July	16	$-\ 77.1$	WRIGHT.

μ *Sagittarii* ($\alpha = 18^h\ 7^m.8$; $\delta = -\ 21°\ 05'$).

1899, June	19	$-\ 75^{km}$	WRIGHT.
1900, May	30	$-\ 76$	WRIGHT.

These measures are subject to an uncertainty of several kilometers, on account of the character of the spectrum.

The negative sign indicates approach toward the solar system, and the positive sign recession from the solar system.

W. W. CAMPBELL.

NOTE ON THE PROBABLE ERROR OF MICROMETER MEASURES OF *EROS*.

During the recent *Eros* campaign for the determination of the value of the solar parallax, a great many observations were made visually with the micrometer. The question of the accuracy of these measures is therefore an important one. In general, the motion of *Eros* was so rapid in both coordinates that the probable error of the mean of a number of settings, even when made in rapid succession, could not be determined in the usual manner by treating the differences between the single settings and the mean as the v's.

But on December 5, 1900, *Eros* ceased its apparent westward motion among the stars and began to move eastward. Consequently on that date its motion in Right Ascension was very slight — only about twenty-two seconds of arc in eight hours.

On the night mentioned, I measured the position of *Eros* with respect to two small stars in the early evening, when it was from three to two hours east of the meridian, and with respect to two other stars later in the night, when it was from four to five hours west of the meridian. In all I made eighteen measures of difference of Right Ascension, each consisting of ten settings with the micrometer. As the ten settings in no case required more than three and a half minutes, the motion of *Eros* could be entirely neglected and their variations from the mean treated as purely accidental errors of measurements.

In this way I found that the average probable error for the mean of ten settings was ± 0″.053, the smallest being ± 0″.036, and the largest 0″.085. During the evening measures the observing conditions were about the average. In the morning the seeing was poor. The average probable error for the evening observations was ± 0″.046, and for the morning ± 0″.058. The distances of the stars from *Eros* varied from 19″ to 133″, and their magnitudes from 9.1 to 12. In both evening and morning observations the two comparison-stars were on opposite sides of *Eros* in Right Ascension. Of the one hundred and eighty settings, eight give residuals from the mean of ten that exceed 0″.50, the largest being —0″.67.

As this use of the measures was not thought of until after they had been made, the results here given may be considered as fairly representing the accuracy, so far as accidental error of measurement is concerned, of my entire series of micrometer measures of *Eros*. R. G. AITKEN.

THE CROCKER ECLIPSE EXPEDITION TO SUMATRA.

The Crocker Eclipse Expedition to Sumatra sailed from San Francisco on February 19th, on the Nippon Maru. The expedition is in charge of Acting Astronomer C. D. PERRINE, who is accompanied by Assistant R. H. CURTISS. The Nippon reached Yokohama on March 11th, two days behind schedule time, unusually heavy weather having prevailed almost continuously. A cablegram from Mr. PERRINE was received at the Lick Observatory on April 5th, announcing the arrival of the expedition at Padang. The eclipse occurs May 17, 9^h 29^m P.M., Pacific standard time.

Weather permitting, it is hoped to secure observations with the following instruments:—

1. Five-inch aperture, 40-foot focus, Clark photoheliograph lens, for recording the details of the inner corona. The exposures will vary from ¼ second up to 2½ minutes, the latter on 18 × 22-inch plates.

2. Five-inch aperture, 67-inch focus, Floyd (Clark) photographic telescope, for securing a series of photographs showing the general features of the corona.

3. Six-inch aperture, 32.6-inch focus, Pierson (Dallmeyer) quadruplet camera, for recording the outer portions of the corona.

4. One-inch aperture, 20¾-inch focus camera, with a large double-image prism in front of its lens; separating the two images about 1¼ degrees. It is hoped that a long and a short exposure can be secured in each of five positions of the prism differing 22½ degrees in position-angle from each other, successively.

In this connection, it may be said that no phase of eclipse work is now more prominent or more important than that of measuring the proportion of polarized light in the corona. The outcome of the numerous discussions in the technical journals has simply been to emphasize the necessity of securing more observations with all the instruments heretofore employed for this purpose. I must confess that the polarization effects observed by some at the eclipse of May 28, 1900, are so strong as to excite suspicion that the results are at least in part of instrumental origin. Granting that the coronal light is largely reflected sunlight, it seems to me that the planes of polarization should not be strongly marked. A reflecting or refracting particle of the corona, situated less than 10′ of arc from the Sun's edge, must be receiving illumination from every visible point of the photosphere, and therefore from a multitude of very different directions. Again, the observation includes not only one illuminated point, but a long line of points lying in the line of sight. For regions reasonably near the Sun's edge, how can the planes of polarization be clearly defined to the extent of revealing a large proportion of polarized light?

5. An efficient one-prism spectrograph, slit radial to Sun, for recording the bright and (possible) dark-line spectrum of the corona, and for the bearing of the results on the question of polarization.

6. An efficient one-prism spectrograph, slit tangential to the Sun, to supplement the preceding instrument.

7. A battery of four* photographic telescopes, 3-inch aperture, 11 ft. 4 in. focus, for recording a possible planet (or planets) *Vulcan*. These are mounted in a large polar axis driven by a clock at the end of a 10-foot sector driving-arm, in such a way that two of them will point east of the Sun, and the other two west of it. It is planned to secure photographs in duplicate of a

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*Two of the lenses were kindly loaned by Harvard College Observatory.

strip of sky along the Sun's equator about 7° × 35°. Successful photographs should record all stars and planets in this region as bright as the 8.5 magnitude. The instrument was set up at Mt. Hamilton in February, and photographs of this same region of sky were taken without the Sun and the hypothetical planets in it. A comparison of the two sets of plates should promptly lead to the discovery of any planet as bright as the 8.5 magnitude which the Sun may have brought into this region of the sky.

The long duration of this eclipse, 6½ minutes, and the probable darkness of the sky, make this the pre-eminent occasion for the *Vulcan* search by photography. At the eclipses preceding 1900, many observing parties secured photographs for this purpose, with short-focus cameras; but owing to the brightness of the sky, and to the short focal lengths employed, the stars recorded were not fainter than the fourth or fifth magnitude; and no unknown objects were recorded. Several observers appear to have been interested in the problem of recording fainter objects, and to have reached similar solutions almost simultaneously. In the month of January, 1900, Mr. PERRINE came to my office to say that he had designed a telescope for efficiency in searching for *Vulcan;* and I was able to say that I had come to a conclusion on the same question. We compared results, and found them very similar. If I remember correctly, Mr. PERRINE'S design called for a 6-inch aperture and 16-foot focus. My dimensions were 5-inch aperture and 15-foot focus. The aim of both had been to reduce the sky-brightness on the plate by increasing the focal length far beyond what we had previously employed at the Indian and other eclipses. On account of the expense of constructing several such instuments, of our distance from manufacturers, of the short duration of the Georgia eclipse ($1^m 25^s$), and of the fact that the expedition would have to start early in April, we decided to plan the instruments for use in Sumatra; and Professor KEELER was spoken to with that in view. Professor WM. H. PICKERING, of Harvard College Observatory, was busy at the same time with a practical solution of the same problem. His results, and plans for employing them at the Georgia eclipse, were published in March, 1900; and two of his four lenses are to be used by Mr. PERRINE in Sumatra. We should have liked to secure lenses of about the dimensions originally planned for by Mr. PERRINE and myself; but the uncertainty as to whether observers could be spared for the

Sumatra expedition was not resolved until January, 1901, too late for the full realization of our ideas.

Lenses of the dimensions planned by Professor PICKERING were employed by several parties in 1900; but so far as I am aware no results have been published. W. W. CAMPBELL.

SCIENTIFIC VISITORS TO THE LICK OBSERVATORY.

The Lick Observatory had a pleasant, but far too brief, visit from the members of the U. S. Naval Observatory and Smithsonian Institution Expeditions to Sumatra, on the afternoon of February 14th. The party included Professor A. N. SKINNER, in charge of the U. S. Naval Observatory Expedition, and Mr. C. G. ABBOT, in charge of the Smithsonian Expedition; Professor E. E. BARNARD, of Yerkes Observatory; Professor W. S. EICHELBERGER, and Assistant Astronomers F. B. LITTELL and G. H. PETERS, of the Naval Observatory; Dr. MITCHELL, of Columbia University; Mr. H. D. CURTIS, of the University of Virginia; and Mr. L. E. JEWELL, of Johns Hopkins University.

Mr. W. R. WARNER, of the well-known firm of WARNER & SWASEY, accompanied by Mrs. WARNER, spent the 26th and 27th of March at Mt. Hamilton, much to the gratification of the members of the staff.

It was a pleasure to be able to show Mr. WARNER that the great telescope is in its original satisfactory condition, — perhaps with some improvements added.

Dr. ARTHUR T. HADLEY, President of Yale University, accompanied by Mrs. HADLEY, visited the Observatory on the night of March 27th. W. W. C.

CHANGES IN THE STAFF OF THE LICK OBSERVATORY.

The Board of Regents of the University of California, at the regular quarterly meeting on March 12th, took action affecting the Lick Observatory staff, as follows:—

Assistant Astronomer C. D. PERRINE was relieved from the duties and title of Secretary.

The title of Acting Astronomer was conferred upon C. D. PERRINE, to hold during his absence from the Observatory, on the Crocker Eclipse Expedition to Sumatra.

Mr. RALPH HAMILTON CURTISS, recently Student Assistant in the Students' Observatory of this University, was appointed

Assistant in the Lick Observatory, to date from February 15, 1901. Mr. CURTISS sailed from San Francisco on February 19th, as Assistant on the Crocker Eclipse Expedition to Sumatra, to return to the Observatory about August 1st.

Mr. CORNELIUS GEORGE DALL, recently Student Assistant in the Students' Observatory, was appointed Assistant in the Lick Observatory from March 15 to July 1, 1901.

Mr. ARCHIBALD JETER CLOUD, University of California, Class of 1900, was appointed Secretary of the Lick Observatory, from March 15, 1901.

W. W. CAMPBELL.

ASTRONOMICAL TELEGRAMS.

(Translations.)

To Lick Observatory,
Mt. Hamilton, Cal.

CAMBRIDGE, MASS., Feb. 22, 1901.
(Received 6:20 A.M., Feb. 24.)

A new star was discovered by ANDERSON at Edinburgh. The position is R. A. $3^h\ 24^m.4$; Decl. $+ 43° 34'$, in the constellation *Perseus*. The magnitude on Feb. 21, was 2.7; color bluish white.

(Signed) EDWARD C. PICKERING.

To W. W. CAMPBELL,
Lick Observatory.

FLAGSTAFF, ARIZ., Feb. 23, 1901.
(Received 6:25 A.M., Feb. 24.)

Please verify new star near *Algol*, zero magnitude.

(Signed) A. E. DOUGLASS.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

On February 8, 1901, the gold medal of the Royal Astronomical Society was granted to Professor EDWARD C. PICKERING, Director of the Harvard College Observatory.

The Royal Academy of Sciences, Sweden, will hold a special session on October 24, 1901, the tercentenary of the death of TYCHO BRAHE. The society has undertaken to issue a facsimile reproduction of TYCHO'S great work, *Astronomiæ Instauratæ Progymnasmata*, of which but five copies are known to exist.

The following notice is copied from *Science*:—

"Each year there is being issued under the editorship of Professor Dr. W. WISLICENUS, from the press of GEORG REIMER, an *Astronomischer Jahresbericht*, or annual review of all kinds of astronomical publications, including writings on geodesy and navigation, if not too remotely connected with astronomy. This work is carried on under the supervision of the Astronomische Gesellschaft. The first volume contains the publications of 1899, and consists of xxiv + 537 pages, 8vo. This was issued in the spring of 1900.

"In the interests of publishers, of readers, and of the nation which he represents, the associate-editor for the United States desires to make the compilation and review of American publications on the above-named subjects as complete as possible. To this end he invites authors and publishers to favor him with the title and place of publication of each book or article issued during 1901 and each subsequent year, or a copy of the same, if convenient, that it may be reviewed for this purpose. The reviews are merely explanatory—not critical. HERMAN S. DAVIS.

"INTERNATIONAL LATITUDE OBSERVATORY, Gaithersburg, Maryland."

At a recent meeting of the Council of the Astronomical and Astrophysical Society of America it was decided to hold the next meeting of the Society at Washington, D. C., in December, 1901, instead of at Denver, in August. This change will doubtless be agreeable to most of our Eastern friends, but hardly so agreeable to some of us on the Pacific Coast who expected to attend the Denver meeting.

Professor FRANCIS E. NIPHER, of Washington University, has recently made some interesting discoveries in photography, which are of special value with regard to over-exposed solar-eclipse plates. Over-exposed plates can be developed as positives, giving fully as much sharpness and detail as the best negatives. He has found also that plates can, with proper exposure, be developed in direct sunlight. An over-exposed plate may be either developed as a negative in a perfectly dark room or as a positive in a light room. Those interested in the subject may find fuller explanations in a short article by Professor NIPHER, in *Science*, February 8, 1901.

Nova Persei was independently discovered by a number of persons. Professor E. B. FROST, at Dartmouth College, noticed the star on February 22d before having received the message announcing Dr. ANDERSON'S discovery. (See *Astronomical Journal*, No. 493.) The following note from Professor W. J. HUSSEY, who is spending his vacation in Washington, D. C., shows that the star was seen early in that part of the country also:

> "The new star in *Perseus*, found by ANDERSON in Scotland, February 21, 1901, was independently discovered in America on the following evening by Mr. RICHARD D. MICOU, a student in the University of Virginia, and by Mr. FARQUHAR, of the Patent Office, Washington, D. C. Mr. FARQUHAR sent a telephone message to the U. S. Naval Observatory announcing his discovery of the new star. Mr. MICOU informed Professor STONE of its existence, who telegraphically announced it to Harvard College Observatory."

During the past three months there has been considerable public discussion concerning the management of the United States Naval Observatory. The naval appropriation bill passed by the last Congress contains the following provision concerning the administration of the affairs of the observatory:—

> "There shall be appointed by the President, by and with the advice and consent of the Senate, from persons not officers of the United States, a board of six visitors to the Naval Observatory, four to be astronomers of high professional standing and two to be eminent citizens of the United States. Appointments to this board shall be made for periods of three years, but provision shall be made by initial appointments for shorter terms, so that two members shall retire in each year. Members of this board shall serve without compensation, but the Secretary of the Navy shall pay the actual expenses necessarily incurred by members of the board in the discharge of such duties as are assigned to them by the Secretary of the Navy or are otherwise imposed upon them. The board of visitors shall make an annual visitation to the observatory, at a date to be determined by the Secretary of the Navy, and may make such

other visitations, not exceeding two in number annually, by the full board or by a duly appointed committee, as may be deemed needful or expedient by a majority of the board. The board of visitors shall report to the Secretary of the Navy at least once in each year the result of its examination of the Naval Observatory as respects the condition of buildings, instruments, and apparatus, and the efficiency with which its scientific work is prosecuted, and shall also report as respects the expenditures in the administration of the observatory. The board of visitors shall prepare and submit to the Secretary of the Navy regulations prescribing the scope of the astronomical and other researches of the observatory and the duties of its staff with reference thereto. When an appointment or detail is to be made to the office of astronomical director, director of the Nautical Almanac, astronomer or assistant astronomer, the board of visitors may recommend to the Secretary of the Navy a suitable person to fill such office; but such recommendation shall be determined only by a majority vote of the members present at a regularly called meeting of the board held in the city of Washington. The superintendent of the Naval Observatory shall be, until further legislation by Congress, a line officer of the navy, of a rank not below that of captain."

According to the above provisions, President McKinley has appointed the following named persons as members of the Board of Visitors: St. Clair McKelway, of Brooklyn; William R. Harper, President of the University of Chicago; Charles A. Young, Director of the Observatory of Princeton University; Ormond Stone, Director of the Leander McCormick Observatory; Edward C. Pickering, Director of the Harvard College Observatory; Asaph Hall, Jr., Director of the Detroit Observatory.

The affairs of the observatory have not only been publicly discussed, but have become complicated by trouble arising between the Superintendent and the Astronomical Director. Superintendent Davis has preferred charges against Director Brown, and these have been settled, by Secretary Long detaching Professor Brown from duty as head of the Nautical Almanac force. The work of the Almanac is now in charge of Professor Harshman.

During the solar eclipse of May 28, 1900, meteorological data were obtained at various stations. The data have been discussed by Mr. H. Helm Clayton and published in a bulletin of the Blue Hill Meteorological Observatory, Annals of the Astronomical Observatory of Harvard College, Vol. XLIII, No. 1. Some highly interesting conclusions were reached, and Mr. Clayton has published a résumé of the work in the Proceedings of the

American Academy of Arts and Sciences, Vol. XXXVI, No. 16. A review of the latter by Professor R. De C. Ward, may be found in *Science* for March 1, 1901. Mr. Clayton shows that the effect of the decrease in temperature is to form an eclipse cyclone, which travels—that is, forms and dissipates—with the velocity of the shadow. He summarizes his conclusions as follows:—

"In brief, the meteorological effects of the eclipse are important—

"(1) Because they confirm so fully Ferrel's theory of the cold-air cyclone;

"(2) Because they show the wonderful rapidity with which cyclonic phenomena can develop and dissipate in the atmosphere; and

"(3) Because they show that cyclones do not necessarily move with the atmosphere, but move with their originating cause, which in the eclipse had a progressive velocity of about two thousand miles an hour."

Mr. Clayton then goes on to consider the subject of diurnal cyclones in the light of the deductions obtained from consideration of meteorological data taken during the eclipse. The thread of Mr. Clayton's argument is sufficiently shown by the following extract:—

"The discovery that the brief fall of temperature attending a solar eclipse produces a well-developed cyclone which accompanies the eclipse shadow, at the rate of about two thousand miles an hour, suggests that the fall of temperature due to the occurrence of night must also produce, or tend to produce, a cold-air cyclone. Since the heat of day produces, or tends to produce, a warm-air cyclone, there must tend to occur each day two minima of pressure, one near the coldest part of the day, and another near the warmest part of the day, with areas of high pressure between them, due to the overlapping of the pericyclones surrounding the cold-air and the warm-air cyclones respectively. These causes must produce entirely or in part the well-known double diurnal period in air-pressure. At any rate, in view of the fact that an eclipse causes a cyclone over half a hemisphere, it will be necessary before rejecting such a theory to show that the fall of temperature at night does not produce a cyclone, or that this cyclone and the corresponding warm-air cyclone of the day do not appreciably influence the barometer.

"The points in favor of the theory that the double diurnal period in pressure is due to two diurnal cyclones, one developed by the cold of night and the other by the heat of day, may be stated in brief as follows: The theory is based on well-known physical laws. The possibility of a cold-air cyclone under conditions similar to the diurnal cyclone is confirmed by the eclipse cyclone. The theory explains the annual oscillation of the time of maxima and minima of pressure in the diurnal period, and explains the occurrence of a third maximum in high northern latitudes in winter. The theory also explains why the warm-air cyclone is well developed over continents, and on clear days, and causes a marked fall in the barometer during the afternoon, while the morning minimum of pressure over continents does not attain an excessive development as compared with that over oceans where there is slight retardation of the air movements on which the fall of the barometer in the cold-air cyclones depends.

"The diurnal cyclones move from east to west, contrary to the motion of ordinary cyclones in temperate latitudes. Their velocity of motion is about one thousand miles an hour at the equator, and diminishes toward the poles."

Father HAGEN, of the Georgetown College Observatory, has published and distributed two charts and catalogues of comparison-stars for *Nova Persei*. These charts and catalogues are very useful and should be obtained by all who have made comparisons of the brightness of the new star. The series of comparisons made at the Students' Observatory, Berkeley, shows that the general decline in the brightness of the star has been varied by frequent increases, the most marked being between March 25th and 26th, when the brightness of the star increased from magnitude 5.1 to magnitude 3.8.

Mr. ANDREW GREIG, of Dundee, Scotland, has kindly forwarded the following:—

ABSTRACT OF A PAPER BY PROFESSOR GRAY ON "THE TIDES AND GENESIS OF THE MOON."

"Professor GRAY, F. R. S., successor to Lord KELVIN at University of Glasgow, lectured recently on 'The Tides and Genesis of the Moon.' The Romans were the first, he said, to detect some of the more prominent of the tidal phenomena, and to assign to these their proper place. He explained and illustrated by means of diagrams the causes of the spring and neap tides, and gave a demonstration of the equilibrium and dynamical theories of the tides. According to the equilibrium theory, there was always high water immediately under the Moon, and also on the opposite side of the Earth at the same time. The motion of rotation of the Earth is retarded by the action between the Earth and the Moon. The Earth rotates, as it were, under the friction-collar formed by the heaped-up waters on the Earth, which are held back by the Moon. Thus, the Earth is, as time goes on, caused to turn on its axis more and more slowly. It is estimated that it falls behind a true clock from this cause by about twenty-two seconds in one hundred years. The action of the Earth upon the Moon was to hasten it in its orbit, so that it was moving outward, increasing the radius of the circle. The consequence was that the length of the day and the length of the month were both increasing; but the length of the day was increasing faster than the length of the month, and thus they were approaching slowly to an equality. When that took place, there would be another change. In consequence of the action of the Sun on the tides upon the Earth, the Moon would begin to come closer in upon the Earth, and unless some other action took place upon the system, the Moon would approach the Earth until it actually fell upon its surface. But we need be under no apprehension as to this happening — it would be several millions of years before such a catastrophe took place.

"With respect to the origin of the Moon, the Earth at an early stage of its existence was a semi-solid, semi-fluid, plastic mass, spinning round on its axis in a period of three to five hours. The period in which a wave would have gone round the Earth would have been about three hours, or nearly equal to the period in which the Earth went spinning round. Now, if a wave produced by the action of the Sun went round the Earth in three hours, each time it returned to receive the Sun's action it would be increased in size. The Earth was spinning at a great rate; and the result would be that parts of it would fly off like the rim of an over-driven fly-wheel, and one or more of these fragments formed the Moon. The Moon continued to go round in a similar orbit to the Earth, but rather more slowly than when it left the Earth. Immediately it began to go further and further out, and this was what it was still doing."

The value of *Eros* for the redetermination of the solar parallax has been noted repeatedly in these *Publications*. But it holds other attractions for astronomers as well. Professor PICKERING early pointed out that it was well situated for the investigation of certain photometric problems; for instance, whether the light of a planet varied inversely as the square of the distance. And now observers with the photometer find that the light of the little planet varies considerably in a very short period of time. Dr. E. VON OPPOLZER seems to have been the first one to call attention to this interesting phenomenon, but his announcement in the *Astronomische Nachrichten* received prompt confirmation from a number of other observers.

From observations so far published the range of variation seems to be considerably greater than one magnitude, and the interval from maximum to maximum or from minimum to minimum to be less than three hours. It has been suggested that the variation is due to the rapid rotation of *Eros* — the opposite hemispheres of the little planet being assumed to possess different albedos, or powers of reflecting light.

Mr. ST. CLAIR MCKELWAY, of Brooklyn, has declined the tender of a place on the Board of Visitors of the United States Naval Observatory, and Secretary LONG has designated for the place Professor CHARLES F. CHANDLER, of Columbia University, New York, who has accepted.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, MARCH 30, 1901, AT 7:30 P. M.

Mr. BURCKHALTER presided. A quorum was present. The minutes of the last meeting were read and approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED MARCH 30, 1901.

Mr. GEO. L. DILLMAN, C. E. . . . . . 917 Grand St., Alameda, Cal.
Mr. EDWARD IRVING . . . . Berkeley, Cal.
LOWELL OBSERVATORY . . . . Flagstaff, Arizona.

REPORT OF THE LIBRARY COMMITTEE.

We, the undersigned Committee of the Society's Library, report as follows: —

During the past year the card index (which was commenced some years ago) of the bound volumes of the library, has been completed. The library now contains 1,144 bound volumes. It is hoped that we may soon commence an index for the pamphlets.

The expenditures from the Alexander Montgomery Library Fund for the year ending March 30, 1901, may be found in the Treasurer's report.

Respectfully submitted,

SIDNEY D. TOWNLEY, *Librarian.*
ROSE O'HALLORAN,
ADELAIDE M. HOBE.

The following resolutions were, on motion, adopted: —

Resolved, That the chairman of the Committee on Publication be not required to pay annual dues.

Resolved, That the Library Committee be empowered to dispose of extra copies of certain books, by sale or exchange, provided the number of copies be not reduced to less than two of each.

Resolved, That the Library Committee be authorized to purchase such additional book cases and shelves as are required; the sums expended not to exceed the amount of interest available.

Adjourned.

MINUTES OF THE ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, MARCH 30, 1901, AT 8 P. M.

The meeting was called to order by Mr. BURCKHALTER. A quorum was present. The minutes of the last meeting were approved. The Secretary read the names of new members duly elected at the Directors' meeting.

The following papers were presented:—

1. Reports of Committees: on Nominations; on the Comet Medal; on Auditing; and Annual Report of the Treasurer.
2. Photographs of the Zodiacal Light, by A. E. DOUGLASS.
3. Photographic Observations of Comet II, 1900, by H. K. PALMER.
4. Planetary Phenomena for May and June, 1901, by M. MCNEILL.

The Committee on Nominations reported a list of names proposed for election as Directors, as follows: Messrs. A. H. BABCOCK, W. W. CAMPBELL, CHAS. S. CUSHING, JOHN DOLBEER, C. B. HILL, E. J. MOLERA, Miss R. O'HALLORAN, Messrs. C. D. PERRINE, WM. M PIERSON, S. D. TOWNLEY, F. R. ZIEL.

For Committee on Publication: Messrs. R. G. AITKEN, S. D. TOWNLEY, J. D. GALLOWAY.

Messrs. MOSES and GALLOWAY were appointed as tellers. The polls were open from 8:15 to 9 P. M., and the persons above named were duly elected to serve for the ensuing year.

REPORT OF THE COMMITTEE ON THE COMET-MEDAL, SUBMITTED MARCH 30, 1901.

This report relates to the calendar year 1900. The comets of 1900 have been:

Comet *a* (unexpected comet), discovered by M. MICHEL GIACOBINI, at the Nice Observatory, on January 31st.

Comet *b* (unexpected comet), discovered by M. BORRELLY, at the Marseilles Observatory, on July 23d, and independently, a little later on the same night, by DR. BROOKS, of Geneva, N. Y.

Comet *c* (unexpected comet), discovered by M. MICHEL GIACOBINI, at the Nice Observatory, on December 20th.

The Comet-Medal has been awarded to the discoverers of comets *a* and *c*, and to the first discoverer of comet *b*, in accordance with the regulations.

Respectfully submitted,

W. W. CAMPBELL,
WM. M. PIERSON,
CHAS. BURCKHALTER.

The Treasurer submitted his Annual Report as follows:—

ANNUAL STATEMENT OF THE RECEIPTS AND EXPENDITURES OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE FISCAL YEAR ENDING MARCH 30, 1901.

GENERAL FUND.

Receipts.

Cash Balance, April 1, 1900		$35 0
Received from dues	$ 831 44	
" " sale of publications	22 50	
" " " " stationery	1 55	
" " advertisements	30 00	
" " Security Savings Bank (interest)	28	
" " Life Membership Fund (loan)	500 00	
" " " " " (interest)	63 58	
" " Donohoe Comet-Medal Fund (engraving four medals, Nos. 36 to 39)	4 00	1.453 35
		$1,488 44

Expenditures.

For publications: printing		$744 55		
" " illustrations	$62 57			
Less payment by Lick Observatory	10 00	52 57		
			$797 12	
Stationery and printing			96 85	
Postages			68 23	
Rent			180 00	
Salary Secretary-Treasurer			180 00	
Expressages			17 98	
Janitor and elevator			6 25	
Gas			85	
Taxes			2 45	
Insurance premiums			22 45	
Telegrams and telephoning			3 05	
Lantern at two lectures			17 00	
Engrossing resolutions and diplomas			20 00	
Dry plates			2 25	
Engraving two comet medals (Nos. 38 and 39)			2 00	
Bank exchanges			77	1.417 25
Cash Balance, March 30, 1901				$71 19

LIFE MEMBERSHIP FUND.

Cash Balance, April 1, 1900		$2,103 95
Interest for 1900		63 58
		$2,167 53
Less transfer to General Fund (interest)	$63 58	
" " " " " (loan)	500 00	563 58
Cash Balance, March 30, 1901		$1,603 95

DONOHOE COMET-MEDAL FUND.

Cash Balance, April 1, 1900	$665 69
Interest for 1900	22 44
	$688 13
Less transfer to General Fund (engraving four medals, Nos. 36 to 39)	4 00
Cash Balance, March 30, 1901	$684 13

BRUCE MEDAL FUND.

Cash Balance, April 1, 1900	$2,500 00
Interest for 1900	77 97
Cash Balance, March 30, 1901	$2,577 97

ALEXANDER MONTGOMERY LIBRARY FUND.

Cash Balance, April 1, 1900		$1,523 11
Interest for 1900		50 55
		$1,573 66
Less expenditures: Hicks-Judd Co., for binding	$13 15	
Physical Review and *American Mathematical Soc'y.*	8 60	
Vierteljahres Schrift	63	
Popular Astronomy, subscription (Vols. 8 and 9)	5 00	
Observatory (14 numbers)	3 02	30 40
Cash Balance, March 30, 1901		$1,543 26

FUNDS.

Balances on Deposit as follows:

General Fund:		
with Donohoe-Kelly Banking Co	$61 15	
" Security Savings Bank	10 04	
		$71 19
Life Membership Fund:		
with San Francisco Savings Union	$553 95	
" German Savings and Loan Society	450 00	
" Hibernia Savings and Loan Society	600 00	
		$1,603 95
Donohoe Comet-Medal Fund:		
with San Francisco Savings Union	$225 98	
" German Savings and Loan Society	223 75	
" Hibernia Savings and Loan Society	234 40	
		$684 13
Alexander Montgomery Library Fund:		
with San Francisco Savings Union	$489 90	
" German Savings and Loan Society	430 18	
" Hibernia Savings and Loan Society	623 18	
		$1,543 26
Bruce Medal Fund:		
with San Francisco Savings Union	$1,287 81	
" Security Savings Bank	643 90	
" German Savings and Loan Society	646 26	
		$2,577 97
		$6,480 50

SAN FRANCISCO, March 30, 1901.

F. R. ZIEL, *Treasurer.*

Examined and found correct.

W. H. LOWDEN,
F. H. MCCONNELL, } *Auditing Committee.*

The Committee appointed to audit the Treasurer's accounts reported as follows, and the report was, on motion, accepted and adopted:—

To the President and Members of the Astronomical Society of the Pacific:

GENTLEMEN — Your committee appointed to audit the accounts of the Treasurer for the fiscal year ending March 30, 1901, have made a careful examination, and find same to be correct.

Yours respectfully,

W. H. LOWDEN,
F. H. MCCONNELL.

March 30, 1901.

The Secretary reported that a bronze replica of the Emperor-Nicolai-Alexandrovich-Medal has been presented to the Society by the Russian Astronomical Society. The thanks of the Society were returned to the donors.

The following resolution was, on motion, adopted:—

Resolved, That all the acts appearing in the minutes of the meetings of the Board of Directors of this Society, as having been done by said Board during the past fiscal year, are here now, by this Society, approved and confirmed.

Adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, MARCH 30, 1901, AT 9:30 P. M.

The new Board of Directors was called to order by Mr. TOWNLEY. A quorum was present. The minutes of the last meeting were approved.

The business in hand being the election of officers and committees for the ensuing year, the following officers and committees, having received a majority of the votes cast, were duly elected:—

President: Mr. JOHN DOLBEER.
First Vice-President: Mr. S. D. TOWNLEY.
Second Vice-President: Miss R. O'HALLORAN.
Third Vice-President: Mr. CHAS. S. CUSHING.
Secretaries: Messrs. C. D. PERRINE and F. R. ZIEL.
Treasurer: Mr. F. R. ZIEL.

Committee on the Comet-Medal: Messrs. CAMPBELL *(ex-officio)*, PIERSON, and BURCKHALTER.

Library Committee: Mr. TOWNLEY, Miss O'HALLORAN, Miss HOBE. Mr. TOWNLEY was appointed Librarian.

The President was authorized to appoint the members of the Finance Committee, and accordingly made the following selection:—

Finance Committee: Messrs. PIERSON, HILL, CUSHING.

The Committee on Publication is composed of: Messrs. R. G. AITKEN, S. D. TOWNLEY, J. D. GALLOWAY.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. John Dolbeer	*President*
Mr. S. D. Townley	*First Vice-President*
Miss R. O'Halloran	*Second Vice-President*
Mr. Chas. S. Cushing	*Third Vice-President*
Mr. C. D. Perrine Mr. F. R. Ziel	*Secretaries*
Mr. F. R. Ziel	*Treasurer*

Board of Directors—Messrs. Babcock, Campbell, Cushing, Dolbeer, Hill, Molera, Miss O'Halloran, Messrs. Perrine, Pierson, Townley, Ziel.

Finance Committee—Messrs. Pierson, Hill, Cushing.

Committee on Publication—Messrs. Aitken, Townley, Galloway.

Library Committee—Mr. Townley, Miss O'Halloran, Miss Hobe.

Committee on the Comet-Medal—Messrs. Campbell (*ex-officio*), Pierson, Burckhalter.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Francisco Rodriguez Rey.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

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The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

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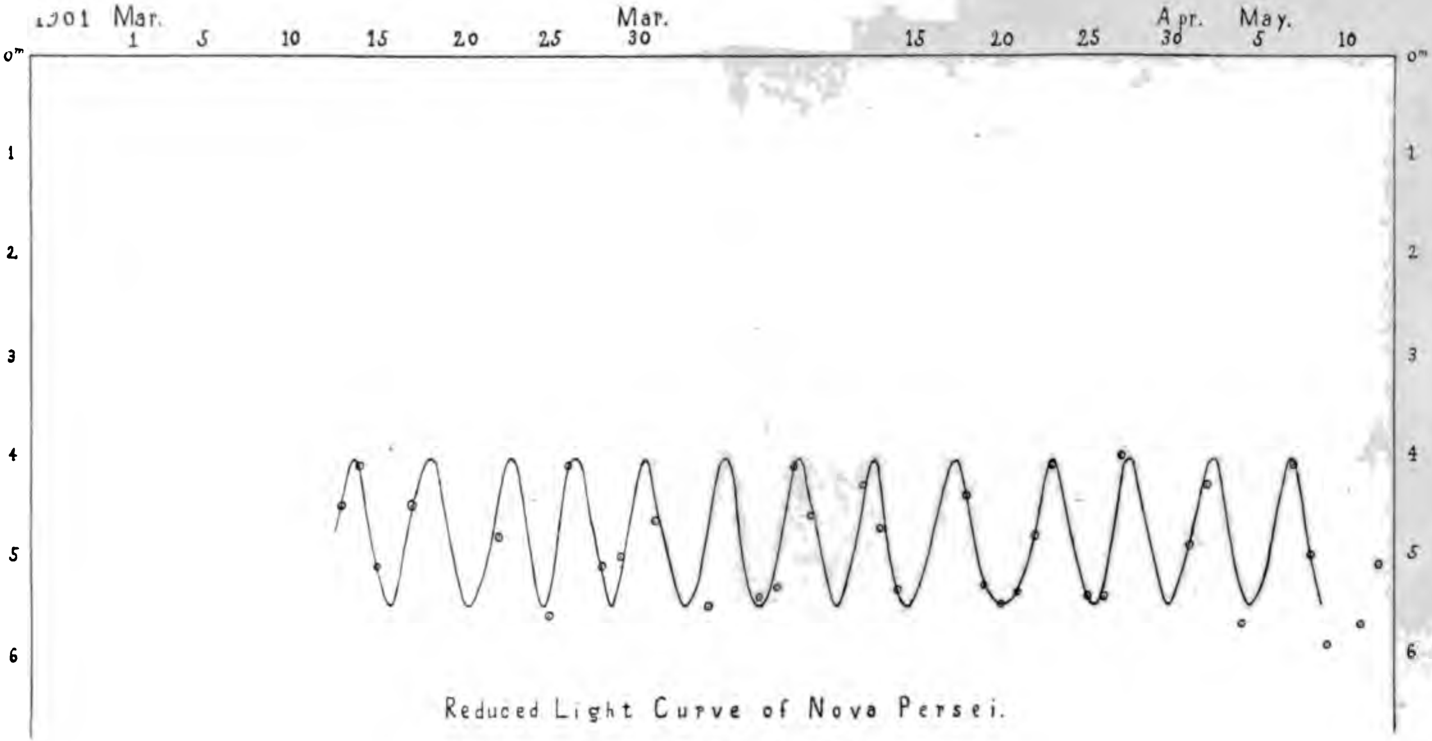

Reduced Light Curve of Nova Persei.

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LIGHT CURVE OF *NOVA PERSEI.*

By SIDNEY D. TOWNLEY.

The new star in *Perseus* was observed at the Students' Observatory on nearly every clear night from February 24th to May 12th. Unfortunately obstructions in the northwestern horizon made it impossible to continue observations after the latter date. It was early noticed that the general decline of the star's brightness was interrupted by frequent increases of brightness. Toward the end of March the results gave strong evidence of a periodicity in the light changes, but it was not until the latter part of April that a sufficient number of observations had been obtained to warrant the announcement that *Nova Persei* had become a variable star of short period. On April 27th Professor LEUSCHNER sent the following telegram, in cipher, to the Harvard College Observatory:—

> "Maxima of *Nova Persei* were observed at Berkeley by TOWNLEY, March 14th, March 26th, April 8th, and April 23d. Range, 1.3 magnitudes. Two, possibly three, secondary maxima."

We were informed that information to the same effect had already been received at Harvard College Observatory from Kiel, and consequently this telegram was not distributed by Professor PICKERING.

Subsequent observations have shown that the secondary maxima are probably of the same magnitude as the others, thus giving a period of about 4½ days from March 13th onward. No definite period can as yet be made out from the small fluctuations noticed previous to that time. The observations made subsequent to March 13th are represented in the accompanying figure; the general decline in brightness having been eliminated in the following way. When the observations were plotted the following maxima were noticed:—

March 14,	$3^m.1$	April 23,	$4^m.3$
" 26,	3 .7	May 7,	4 .3
April 8,	4 .1		

The maximum of March 14th was first brought down to that of March 26th by adding 0.6 magnitude to the value for March 14th and to each observation between March 14th and 26th $0^m.6$ times the ratio of "interval from date of observation to March 26th" and "twelve days." These magnitudes were then increased by the constant amount $0^m.4$ to bring them to the level of the maximum of April 8th. The observations between March 26th and April 8th were increased by proportional parts of $0^m.4$ in the same way as above. Magnitudes from April 8th to 23d were decreased by proportional parts of $0^m.2$, and all magnitudes after April 23d were decreased by $0^m.2$. Thus the five maxima were all brought to the same level, and the plotted result is seen in the accompanying figure. An inspection shows that the observations are very well represented by a curve which shows slight deviations from a symmetrical curve of a period of about 4.6 days. Very few portions of the curve have no observations to depend upon. The last six observations are somewhat uncertain on account of the small altitude, twilight, obstructing trees, etc. They seem to indicate that the general decline at that time was much more than $0^m.2$ of a magnitude. The twelve periods of the curve extend over 54.5 days, which gives 4.54 days for the average period; but if the last nine only are taken, a period of 4.61 days is obtained. The latter observations show a tendency towards a lengthening of the period. The information from Kiel, which was received here about May 5th, reported a three-day period between March 20th and 30th, when observations here were unfortunately interrupted by bad weather. A month later, however, my observations on ten consecutive days, April 18th to 27th, except April 24th, show clearly that a three-day period did not then exist.

The curve must not be taken too literally. It is not very likely that all of the maxima were of exactly the same height, nor all of the minima of the same depth, as is indicated in the curve drawn. The observations seem to show, too, that some of the turning-points are quite sharp and others rather flat, but the number of observations at present available would not justify an attempt to draw anything more than a general curve. Although the period of this variable is short, still it is not likely that it will show the marked characteristic, great regularity, of the two classes of short-period variables. It will be found rather, I think, to behave like the long-period variables in which exact uniformity of changes is always lacking. The second, third, fifth, and sixth maxima; the first, second, fifth, and seventh minima have but few observations to support them, and I should not be surprised to see these parts of the curve considerably modified when other observations become accessible.

OBSERVATIONS.

The observations were made by the same methods that I have used in previous variable star-work, and which are fully explained in the Publications of the Washburn Observatory, Vol. VI, Part 3. Both of the standard methods were used. After the first few nights the comparison-stars employed were selected from the charts and catalogues sent out from the Georgetown College Observatory. The magnitudes of the comparison-stars have been carefully investigated. After examining several sources, it was decided to use the magnitudes given in the later volumes of the Harvard College Observatory photometric work. It is essential that the magnitudes adopted shall conform to some definite system, and this can be obtained better perhaps by taking the results of one investigation than by combining the results of several; at least the latter method could be made the more efficient only by an elaborate discussion, which it did not seem necessary to make at this time. The comparison-stars used are given in the following table; the adopted magnitudes having been obtained from volumes 44 and 45 of the Annals of the Harvard College Observatory. The magnitude of ρ *Persei* was obtained from comparisons on March 10th, 11th, 12th, and 14th.

COMPARISON - STARS.

Reference Letter.	Star.	Adopted Magnitude.	Reference Letter.	Star.	Adopted Magnitude.
a	α *Aurigæ*	0.24	*f*	α *Geminorum*	1.61
b	β *Orionis*	0.30	*g*	α *Persei*	1.85
c	α *Canis Minoris* ..	0.46	*h*	β *Andromedæ*	2.17
d	α *Tauri*	1.09	*i*	α *Ursæ Minoris* ..	2.20
e	β *Geminorum*	1.25	*j*	γ *Cassiopeiæ*	2.22

Reference Letter.	Star.	Adopted Magnitude.	Reference Letter.	Star.	Adopted Magnitude.
k	γ *Andromedæ*.....	2.26	*s*	ρ *Persei*.........	3.42
l	β *Persei*..........	2.30	*t*	ν *Persei*....	3.90
m	β *Cassiopeiæ*......	2.44	*u*	κ *Persei*.........	4.04
n	δ *Cassiopeiæ*......	2.78	*w*	ι *Persei*.........	4.20
o	ζ *Persei*.........	2.83	*x*	*Flamsteed 32*....	5.13
p	ε *Persei*.........	2.88	*y*	*Flamsteed 36*....	5.33
q	γ *Persei*.........	3.05	*z*	*Flamsteed 30*....	5.39
r	δ *Persei*.........	3 06	*a′*	B. D. + 44° 734	6.48

Following are the observations upon which the foregoing results depend. The weights of the individual observations have been assigned, arbitrarily, after considering the circumstances and conditions under which the observations were made. The chief factors which affect the accuracy of such observations are: distance between the stars compared; number of steps estimated, or difference in magnitude of the two comparison-stars used; difference in color of the stars. The observations made by the step-method have been reduced on the assumption that one step equals one tenth of a magnitude, which seems justified by the fact that in the long series of observations made at the Washburn Observatory several years ago, the value of one step was found to be 0.92 of a magnitude. v stands for *Nova Persei*. In the column headed "instrument," E stands for naked-eye observations; G for field-glasses; F for 4.5 centimeter finder of equatorial; S for surveyor's transit; C for 15.4 centimeter Clark equatorial.

OBSERVATIONS.

Date. G. M. T.	Comparisons.	Nova.	Wt.	Weighted. Mean.	Instrument.	Remarks.
1901		m		m		
Feb 24.69...	$v \overset{=}{<} b$	0.35	2	...	E	
	a 5 e	0.75	2	...	E	
	a 3-4 e	0.59	2	...	E	Made by R. A. Curtiss.
	a 2-3 i	0.73	1	0.6	E	
Feb. 25.69...	b 3 i	0.84	1	...	E	
	a 8-9 e	1.10	2	...	E	
	v = e	1.25	1	...	E	Position difficult.
	b 6-5 l	0.73	1	...	E	Moon interferes.
	c 6 d	0.84	1	1.0	E	Moon interferes.

Date. G. M. T.	Comparisons.	Nova.	Wt.	Weighted. Mean.	Instrument.	Remarks.
1901		m		m		
Feb. 26.77...	d 3-4 i	1.47	2	...	E	
	b 8 i	1.84	1	...	E	
	e 5 i	1.72	2	...	E	
	e 4 f	1.78	2	1.7	E	
Feb. 27.63...	d 8-9 i	2.03	2	...	E	
	v = g	1.85	3	...	E	
	d 7 k	1.91	2	...	E	
	h 4 k	2.21	2	2.0	E	
Mar. 1.65...	g 7-8 l	2.19	...	2.2	E	Clouds prevent other observations.
Mar. 2.65...	g 4 l	2.03	2	...	E	
	g h 1 k v 2 l	2.10	4	...	E	
	i 2 v	2.40	1	2.1	E	
Mar. 3.67...	l 3 p	2.47	1	...	E	
	l 1-2 r	2.41	1	...	E	
	g 2 h i 1 k 2 l 2 v	2.60	3	2.5	E	
Mar. 4.65...	g 3 r	2.21	1	...	E	
	g 3 p	2.16	1	...	E	
	4 n	2.44	1	2.3	E	
Mar. 5.65...	v l j	2.26	5	...	E	v as red as d.
	m 1 v	2.44	2	...	E	
	i 1-2 v	2.35	2	2.3	E	
Mar. 6.65...	v 3 s	3.12	1	...	E	
	l 7 s	3.08	1	3.1	E	
Mar. 8.63...	l 4 s	2.74	...	2.7	E	
Mar. 10.75...	l 3-4 s	2.69	1	...	E	
	n 2 v	2.98	2	...	E	
	l 7-8 p	2.73	3	...	E	
	l 7 r	2.83	3	2.8	E	
Mar. 11.69...	l 9 s	3.32	1	...	E	
	v 1 s	3.32	1	...	E	
	r 1 v	3.16	3	...	E	
	p 2-3 v	3.13	2	...	E	
	p 4 u	3.34	1	3.2	E	
Mar. 12.75...	p v 2 r	2.87	4	...	E	
	p 1 u	3.00	1	...	E	
	q 1-2 v	3.20	2	...	E	
	l 6 s	2.97	1	3.0	E	
Mar. 13.7 ...	p 4 u	3.34	2	...	E	
	r 5-6 u	3.60	3	...	E	
	p 5 t	3.39	2	...	E	
	r 6-7 t	3.60	3	3.5	E	

Date. G. M. T.	Comparisons.	Nova.	Wt.	Weighted. Mean.	Instrument.	Remarks.
1901		m		m		
Mar. 14.71...	r 1 v	3.16	3	...	E	
	p 2 t	3.08	3	...	E	
	q 1 v	3.15	2	...	E	
	l 7 s	3.08	1	...	E	
	o v	2.83	2	3.1	E	Stars twinkle badly.
Mar. 15.77...	u 2 t 1 v	4.14	...	4.1	G	
Mar. 17.71...	r 7 t	3.65	3	...	G	
	r 5 u	3.55	3	...	G	
	p 7 t	3.59	3	...	G	
	p 5 u	3.46	2	3.6	G	
Mar. 22.74...	v w	4.20	3	...	G	
	u 3 x	4.37	2	...	G	
	t 2–3 v	4.15	2	4.2	G	
Mar. 25.65...	x 1 v	5.23	2	...	G	
	u 7–8 z	5.05	1	...	G	Difficult with field glasses.
	x 2 y	5.17	2	5.2	G	
Mar. 26.71...	v 2 u t	3.77	2	...	F & S	
	r 6–7 u	3.70	1	3.7	F & S	
Mar. 28.67...	u 6–7 x	4.75	1	...	G	
	t 7–8 x	4.82	1	4.8	G	
Mar. 29.69...	u 5 x	4.59	1	...	G	
	t 7 x	4.76	1	4.7	G	
Mar. 31.67...	u 3 x	4.37	1	...	G	
	t 4 x	4.39	1	4.4	G	
Apr. 3.66...	x 3–4 z	5.22	3	...	G	Difficult with field glasses.
	y 3 v	5.66	1	5.3	G	
Apr. 6.7 ...	x 8 z	5.34	3	...	G	v just visible without glasses.
	v 2 z	5.19	2	...	G	
	v z	5.33	3	5.3	G	
Apr. 7.7 ...	x 8 z	5.34	1	...	G	
	v y	5.33	1	5.3	G	
Apr. 8.70...	t 1 u 1 v	4.12	...	4.1	G	
Apr. 9.67...	t 6–7 x	4.70	1	...	G	
	u 5 x	4.59	1	4.6	G	
Apr. 12.7 ...	u 2–3 v	4.29	...	4.3	G	Uncertain on account of clouds.
Apr. 13.69...	t 7 x	4.76	1	...	G	
	u 7–8 x	4.85	1	4.8	G	
Apr. 14.67...	v y	5.33	2	...	G	
	z 2 v	5.59	1	5.4	G	

Date. G. M. T.	Comparisons.	Nova.	Wt.	Weighted. Mean.	Instrument.	Remarks.
1901		m		m		
Apr. 18.67...	u 5 x	4.59	1	...	F	
	t 4 x	4.38	1	4.5	F	
Apr. 19.67...	v z	5.39	3	...	G	
	y 2 v	5.53	2	5.4	G	
Apr. 20.67...	z 2 v	5.59	...	5.6	G	
Apr. 21.67...	v z	5.39	2	...	F	
	y 2 a′	5.56	1	...	F	
	y 2–3 v	5.58	1	5.5	F	
Apr. 22.68...	v 1 x	5.03	3	...	F & C	
	u 8 x	4.91	2	5.0	F & C	
Apr. 23.67...	t 3 x	4.27	1	...	F & C	
	u 2 x	4.26	1	4.3	F & C	
Apr. 25.68...	y 2 a′	5.56	1	...	F & C	
	z 2–3 v	5.64	1	5.6	F & C	
Apr. 26.67...	y 3–4 a′	5.73	2	...	F & C	
	z 2 v	5.59	3	5.6	F & C	
Apr. 27.67...	t 3–2 x	4.21	1	...	G F & C	
	u 2 x	4.26	1	...	G F & C	
	u 2 v	4.24	1	4.2	G F & C	
May 1.67...	v x	5.13	...	5.1	F & C	
May 2.68...	t 5 x	4.51	1	...	F & C	
	u 4 x	4.48	1	4.5	F & C	
May 4.68...	y 7 a′	6.14	1	...	F & C	Seeing poor.
	z 3–4 v	5.74	1	5.9	F & C	
May 7.68...	t 3 x	4.27	1	...	F	
	u 2–3 x	4.26	1	4.3	F	
May 8.68...	x 5 y	5.23	...	5.2	F & C	
May 9.68...	y 7 a′	6.14	...	6.1	F & C	Difficult—low altitude.
May 11.68...	y 5 a′	5.90	...	5.9	F & C	Very uncertain.
May 12.68...	v y	5.33	..	5.3	F & C	Very uncertain.

NOTE.—Since the above was written I have received through the courtesy of Director CAMPBELL, of the Lick Observatory, the results of a very complete series of observations made by Mr. AITKEN. Bulletin No. 17 of the Yerkes Observatory, containing Mr. PARKHURST's observations, and No. 6, Vol. LXI, *Monthly Notices of Royal Astronomical Society*, containing observations by the Oxford observers, have been received also. These observations have been plotted, and in general confirm the curve from March 20th on, strengthening many of its weak points. The eighth and eleventh maxima and the twelfth minimum are the only ones which are not strengthened by additional observations. Between March 10th and 16th, however, the observations do not support the curve as drawn. They show either a period of about one day, or else some large errors of observation. My observation of April 3d, which falls considerably from the curve, is confirmed by one made by Mr. PARKHURST showing that the minimum was delayed about a day.

These additional observations show, as I expected they would, that the actual curve is considerably more irregular than the one drawn.

Mr. AITKEN's observations, which extend to May 19th, give two additional maxima, May 13.5 and about May 18.5, the last on the curve of the accompanying figure being May 7.7, G. M. T. This shows almost conclusively, what was previously suspected, that the period is lengthening.

A preliminary investigation of all the data available leads to the following conclusions:—

1. From February 24th to March 19th the brightness of the star decreased in an irregular way about three magnitudes, but there is strong evidence of a gradually lengthening period throughout this time. A period of about a day from March 10th to 15th seems almost certain.

2. From March 20th to May 19th there was a very slight general decline in brightness, but a well-marked period, which gradually lengthened from three and a half to five days. The range between maxima and minima has an average value of about 1.5 magnitudes.

A modification of the tide theory offers an explanation of the phenomena observed in *Nova Persei*. Suppose a near approach between two bodies occurs; one a body of large mass, which has cooled so that a thin crust has been formed, making the body non-luminous, a condition in which it is thought our Sun will be about 20,000,000 years hence; the other a body of small mass and solid, like the Moon, for example. Let the directions and velocities of motion of these two bodies be such that a very close approach, not a collision, takes place. Suppose the masses of the bodies are such that the larger is not sensibly disturbed in its motion, but that the smaller is profoundly disturbed. Its orbit will be changed from a straight line to a parabola, an hyperbola, or a very elongated ellipse, depending upon the initial velocity. At a very near approach of the two bodies the smaller will be swept rapidly around the larger, like a comet around the Sun; the attraction of the smaller may be sufficient to burst the crust of the larger and produce a sudden outburst of the heated matter within. As the smaller body moves rapidly around the larger, this rent in the crust will be carried forward and the light of the star will increase rapidly, and a tremendous tidal-wave will have been set up. As the smaller body moves away from the larger, the tidal-wave will continue to move, sweeping away the accumulated vapors, thus producing a maximum of brightness at each return of the wave to the line of sight of the observer. On account of internal friction, however, the velocity of propagation of this wave will continually decrease and the period of fluctuation in brightness will gradually increase, and the star will finally settle down to its former state.

This explanation is offered tentatively. I hope soon to thoroughly investigate the suggestions here made.

A REVIEW OF THE "CHAPTERS ON THE STARS" BY PROFESSOR SIMON NEWCOMB, IN THE *POPULAR SCIENCE MONTHLY*, JULY, 1900,—MARCH, 1901.

By J. D. Galloway.

In the *Popular Science Monthly* for March of this year, there is concluded a notable contribution to the literature of popular astronomy in the "Chapters on the Stars" by Professor Simon Newcomb. Professor Newcomb has reviewed the entire field of our knowledge of the stars, and has presented the subject with the least use of technical terms and demonstrations possible, in order to conform to the general character of the magazine in which the articles appeared. This has not, however, prevented him from dealing with the subject in the clear and lucid manner which characterizes his other works on similar subjects.

Beginning with the statements as to our knowledge of the southern heavens some thirty years ago, he traces the historical development of that work, referring especially to the history of Cordoba Observatory in the Argentine Republic, under Gould, that of the Royal Observatory at the Cape of Good Hope, under Gill, and of the Observatory of Harvard University at Arequipa, Peru.

The development of the spectroscope is then referred to with the advancement made in the measurement of star-motions in the line of sight, originating with Sir William Huggins and now being so successfully carried on by Campbell. Following this, is a short discussion of the comparative dimensions of the solar system and its position among the stars.

MAGNITUDES OF THE STARS.

The second chapter deals with the magnitudes of the stars. A description of the photographic and photometric systems of measurement is given and the difficulties of both are mentioned. The magnitude of the Sun, based on the results of Wollaston, Bond, and Zöllner is —26.4, from which it results that the Sun gives us 10,000,000,000 times the light of *Sirius*, the brightest star, and 91,000,000,000 the light of a star of magnitude one. To make our Sun shine with the intensity of the light of *Sirius*, it would be necessary to remove it to a point 100,000 times its

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present distance from us. A conclusion drawn from these researches is that our Sun is smaller than the brighter of the stars.

CONSTELLATIONS AND STAR-NAMES.

The subject of the constellations and the names of the stars receives considerable attention. Of the constellations, the astronomical world now recognizes eighty-nine, four being counted in the subdivided constellation of *Argo* as arranged by Dr. GOULD. Considerable confusion still exists as to the boundaries of the constellations and the names of some of the stars in them. The method BAYER originated in 1601, which gives stars the names of the letters in the Greek alphabet, is followed.

CATALOGUING AND NUMBERING THE STARS.

A description of the method of locating the position of stars by Declination and Right Ascension is given, together with an historical review of the efforts to catalogue the stars. PTOLEMY, who lived A. D. 150, made a catalogue of 1,030 stars, but the roughness of his instruments introduced considerable error into the results. The catalogue of ARGELANDER and SCHÖNFELD, extending to 22° of South Declination, enumerates 310,000 stars, while the work as continued at the Cordoba Observatory from this point to 42° South Declination gives 340,000 more. The entire work would give more than 800,000. Photographic catalogues of the southern heavens have been made by GILL, but the work of making a photographic map of the entire heavens is now being carried out as an international enterprise, with headquarters at Paris, instruments of a uniform plan being made for the purpose. For the number of lucid stars, PICKERING gives 5,333, while SCHIAPARELLI counts 4,303. If the results of the *Durchmusterung* of Cordoba Observatory be extended to the entire sky, the number of stars down to the tenth magnitude is 2,311,000; but this is open to doubt. The international photographic chart must be completed before a correct estimate of the number of stars can be made.

THE SPECTRA OF THE STARS.

One of the principal branches of modern astronomy is that of spectroscopy, and considerable space is devoted to an explanation of the principles underlying the spectroscope. Plates of the spectra of some of the larger stars accompany the text, and the chapter closes with the statement that "the most interesting conclusion drawn from observations with the spectroscope is that the stars are composed, in the main, of elements similar to those found in our Sun. As the latter contains most of the elements found on the Earth, and few or none not found there, we may say that Earth and stars seem to be all made out of like matter. It is, however, not yet easy to say that no elements unknown on the Earth exist in the heavens. It would scarcely be safe to assume that, because the line of some terrestrial substance is found in the spectrum of a star, it is produced by that substance. It is quite possible that an unknown substance might show a line in appreciably the same position as that of some substance known to us. The evidence becomes conclusive only in the case of those elements of which the spectral lines are so numerous that when they all coincide with lines given by a star, there can be no doubt of the identity."

PROPER MOTION OF THE STARS.

The question as to the motion of the stars is answered by Professor NEWCOMB in the affirmative. In the chapter on the proper motion of the stars, he says:—

"We may assume that the stars are all in motion. It is true that only a comparatively small number of stars have been actually seen to be in motion; but as some motion exists in nearly every case where observations would permit of its being determined, we may assume the rule to be universal."

Yet this motion is very slight, and

"If HIPPARCHUS or PTOLEMY should rise from his sleep of 2,000 years — nay, if the earliest priests of Babylon should come to life again and view the heavens, they would not perceive any change to have taken place in the relative positions of the stars."

Yet the actual motions, as compared with terrestrial standards are very rapid. *Arcturus* moves from 200 to 300 miles a second, and the variation in its position can be noted in a few days, such are the refinements of modern instruments. Most of the star-motions are slower than this, ranging "from an imperceptible quantity up to 5, 10, or 20 miles a second."

The star of greatest known proper motion was discovered by KAPTEYN, of Gröningen, in 1897, co-operating with GILL and INNES, of the Cape Observatory. Rapid though its motion is,

"it would require nearly 150,000 years for the star to make a complete circuit of the heavens, if it moved around the Sun uniformly at its present rate."

Groups of stars move together as one system, the *Pleiades* being an example, they having been

"found to move together with such exactness that up to the present time no difference in their proper motion has been detected."

Of motions in the line of sight, or radial motions, Professor Newcomb says:—

> "No achievement of modern science is more remarkable than the measurement of the velocity with which the stars are moving to or from us."

This result is obtained by the measurement of the minute difference in position of a given line in the spectrum of a moving star, as compared with the position of the same line in the spectrum formed by the same substance rendered incandescent in the tube of the telescope. This method of measurement was put in practice by Sir William Huggins, and some of the best work is now being done by Professor Campbell at the Lick Observatory with the Mills spectrograph.

A study of the motions of the stars by these methods has led to the discovery of the motion of the solar system, which is stated by Professor Newcomb thus:—

> "The apex of the solar motion is in the general direction of the constellation *Lyra*, and probably very near the star *Vega*, the brightest of that constellation."

While the data as to the rate of the Sun's motion is meager, only some fifty stars having been observed, yet Kapteyn

> "has derived results which seem to show that the actual velocity of the solar system through space is sixteen kilometers, or ten miles, per second."

VARIABLE STARS.

The fact that some of the stars vary in brightness was known as early as 1596, but it was only in the early part of the nineteenth century that Argelander reduced the study of the variable stars to a system. According to Chandler's catalogue, there are 280 of these objects which have been fairly well made out. The "new stars" which blaze out and then fade away are not included in the term "variable stars," but those which go through a regular cycle of change in a definite interval of time. But even in periodic stars, the period is more or less variable.

> "The periodic stars show wide differences, both in the length of the period and in the character of the changes they undergo. In most cases they rapidly increase in brightness during a few days or weeks, and then slowly fade away, to go through the same changes again at the end of the period. In other cases they blaze up or fade out, from time to time, like the revolving light of a lighthouse. Some stars are distinguished more especially by their maximum, or period of greatest brightness, while others are more sharply marked by minima, or periods of least

brightness. In some cases there are two unequal minima in the course of a period."

Three stars which may be seen by the naked eye illustrate the three general types of variable stars, *o Ceti*, called also *Mira Ceti*, *β Persei*, or *Algol*, and *β Lyræ*.

As to the first, *o Ceti*, its variations are quite irregular. Sometimes, when at its brightest, it rises nearly or quite to the second magnitude. At other times its maximum brightness scarcely exceeds the fifth magnitude. No law has been discovered by which it can be predicted whether it shall attain one degree of brightness or another at maximum. Its minima are also variable. Sometimes it sinks only to the eighth magnitude; at other times to the ninth or lower. As with other stars of this kind, it brightens up more rapidly than it fades away. The period also varies in an irregular way. As to the cause of variation,

> "the most plausible view seems to be that changes of a periodic character, involving the irruption of heated matter from the interior of the body to its surface, followed by the cooling of this matter by radiation, are going on in the star."

The star *Algol*, or *β Persei*, is a type of the second class of variables. It is nearly of the second magnitude, but

> "at intervals of somewhat less than three days, it fades away to nearly the fourth magnitude for a few hours and then slowly recovers its light.'

The generally accepted explanation of the variation is that the star is double, the companion being dark and of somewhat lesser size than the bright one.

The star *β Lyræ* illustrates the third general class of variables. It varies nearly a degree in brightness, but the rate of variation, unlike *Algol*, is uniform. Its period is thirteen days, but there are two waves of maxima and minima, one maximum being brighter than the other. According to Professor G. W. MEYERS, of Indiana,—

> "*Beta Lyræ* consists of two bodies, gaseous in their nature, which revolve around each other, so as to be almost touching. They are of unequal size. Both are self-luminous. By their mutual attraction, they are drawn into ellipsoids. The smaller body is darker than the other. When we see the two bodies laterally, they are at their brightest. As they revolve, we see them more and more end on, and thus the light diminishes. At a certain point one begins to cover the other and hide its light. Thus the combined light continues to diminish, until the two bodies move across our line of sight. Then we have a minimum. At

one minimum, however, the smaller and darker of the two bodies is projected upon the brighter one, and thus diminishes its light. At the other minimum, it is hiding behind the other, and therefore we see the light of the larger one alone."

Variable stars exist having some of the characteristics of each of these three types, so that no well-defined system of classes can be established.

THE DISTANCE OF THE STARS.

The distance of the Earth from the stars has always been a subject of much interest to mankind. As the stars remain fixed in direction to all ordinary observation, the conclusion has been drawn that the Earth was fixed in space. The absence of any swing deceived PTOLEMY, and was advanced as an argument against the Copernican system. Modern instruments and methods have at last detected the swing and measured it. Professor NEWCOMB enters into a detailed explanation of parallax and the history of the measurements. Several methods of measurement are used, and stars with a large proper motion are generally selected. The base line of such a measurement is the diameter of the Earth's orbit; about 184,000,000 miles. Yet with this enormous distance, it is possible to measure the parallax, or difference in direction, of but few stars. Some sixty-two have been measured, and many have been found to be without sensible parallax; in other words, the star seen from the two extremities of the Earth's orbit, appears to be in exactly the same direction. The actual distance is far beyond human conception, but it may be stated that the star *α Centauri*, with a parallax of nearly one second, is distant from us more than two hundred thousand times the distance of the Earth from the Sun.

BINARY AND MULTIPLE SYSTEMS.

Sir WILLIAM HERSCHEL was the first to notice that many stars which to the unaided vision seemed single were really composed of two stars in close proximity to each other. To these the general term of "double stars" is given. Only those stars which are really double are considered, those which are optically double being of no particular interest. Regarding the number of such stars, Professor NEWCOMB says:—

"With every increase of telescopic power so many closer and closer pairs are found that we cannot set any limit to the number of stars that may have companions," and "no estimate can be made of the actual number of double stars in the heavens."

> "The great interest which attaches to double stars arises from the proof which they afford that the law of gravitation extends to the stars."

Where two stars revolve around a common center of gravity the term "binary system" is applied to them; yet there are systems where three or four stars form a system.

> "The times of revolution of the binary systems are so long that there are only about fifty cases in which it has been determined with any certainty."

The shortest period is about eleven years.*

> "In the large majority either no motion at all has been detected or it is so slow as to indicate that the period must be several centuries, perhaps several thousand years."

Such a star is *Castor*, or α *Geminorum*. Professor SEE gives twenty-eight periods of less than one hundred years.

SPECTROSCOPIC BINARY SYSTEMS.

In addition to the binary systems discovered by the telescopes, the spectroscope has proved the existence of another class of double stars, usually termed "spectroscopic binary systems." Of these Professor NEWCOMB says that

> "Among the many striking results of recent astronomical research, it would be difficult to name any more epoch-making than the discovery that great numbers of the stars have invisible dark bodies revolving round them of a mass comparable with their own."

The presence of the dark companion is detected by the displacement of the lines of the spectrum of the bright star. In the case of the two stars of a binary system revolving around a center of gravity, the effect produced is as if the bright body alternately advanced and receded. This would result in a displacement of the spectral lines, first to one side and then to the other, of the normal position of the body at rest. The spectroscopic binary systems are very close as regards the distance between the components, and a gap exists between them and the telescopic binary systems, which is being filled as our telescopes increase in power.

> "We naturally infer that there is no limit to the proximity of the pairs of stars of such systems, and that innumerable stars may have satellites, planets, or companion stars so close or so faint as to elude our powers of observation."

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*See, however, Professor HUSSEY's orbit of δ *Equulei* in No. 76 of these *Publications*.

STAR CLUSTERS.

Other interesting features of the heavens are the star clusters. Faint patches of light as seen by the eye are resolved by the telescope into masses of bright stars.

> "In many cases the central portions of these objects are so condensed that they cannot be visually resolved into their separate stars, even with the most powerful telescopes." "The most remarkable and suggestive feature of the principal clusters is the number of variable stars which they contain. The richest in variables is *Messier 3*, in which one variable has been detected among every seven stars. . . . Very remarkable, at least in the case of ω *Centauri*, is the shortness of the period of the variables. Out of one hundred and twenty-five found, ninety-eight have periods less than twenty-four hours, . . . the range in brightness being two magnitudes."
>
> "Perhaps the most important problem connected with clusters is the mutual gravitation of their component stars. Where thousands of stars are condensed into a space so small, what prevents them from all falling together into one confused mass? Are they really doing so, and will they ultimately form a single body? These are questions which can be satisfactorily answered only by centuries of observation; they must, therefore, be left to the astronomers of the future."

NEBULÆ.

The nebulæ, which exist in different parts of the sky, form another very impressive subject for study. Some few, as the Great Nebula in *Orion*, may be seen by the naked eye. They are of many forms, but in a majority the spiral shape has been found. Some are in the form of rings, as the one in *Lyra*. Others seem to be scattered in space without form, the nebulous mass in *Cygnus* being an example. Others have the form of discs, and are called "planetary nebulæ."

> "It is impossible to estimate the number of nebulæ in the heavens. . . . KEELER estimated the whole number to be several hundred thousand . . . A curious fact connected with the distribution of nebulæ over the sky is that it is, in a certain sense, the reverse of the stars. The latter are vastly more numerous in the regions near the Milky Way and fewer in number near the poles of that belt. But the reverse is the case with the nebulæ proper. . . . Perhaps the most obvious suggestion would be that in these two opposite nebulous regions the nebulæ have not yet condensed into stars. This, however, would be a purely speculative explanation."
>
> "The most interesting question connected with these objects is that of their physical constitution. HUGGINS and SECCHI found independently that the light of the Great Nebula in *Orion* formed a spectrum of bright lines, thus showing the object to be gaseous."

"This was soon found to be true of nebulæ in general, that in *Andromeda* being an exception, as it gives a more or less continous spectrum."

"Beyond the general fact that the light of a nebula does not come from solid matter, but from matter of a gaseous or other attenuated form, we have no certain knowledge of the physical constitution of these bodies."

The spectrum of a great number shows a bright line "which does not correspond to the line of any known substance. The supposed matter which produces it has, therefore, been called *nebulium.*" Another conclusion based on their immense dimensions is that they are of extreme tenuity.

MASSES AND DENSITIES OF THE STARS.

Closely connected with the different phenomena to be seen in the heavens lies the question of the size of the stars.

"The spectroscope shows that, although the constitution of the stars offers an infinite variety of detail, we may say, in a general way, that these bodies are suns. It would perhaps be more correct to say that the Sun is one of the stars and does not differ essentially from them in constitution. The problem of the physical constitution of the Sun and stars may, therefore, be regarded as the same. Both consist of vast masses of incandescent matter at so exalted a temperature as to shine by their own light. All may be regarded as bodies of the same general nature. . . . In a few cases an approximate estimate of the density of the stars may be made."

These are binary stars whose parallax or distance from us is known.

"But there is a remarkable law which, so far as I know, was first announced by PICKERING, by virtue of which we can determine a certain relation between the surface brilliancy and the density of a binary system without knowing its parallax."

Here follows a demonstration which space will not permit following, but the conclusion arrived at is that

"the stars in general are not models of our Sun, but have a much smaller mass in proportion to the light they give than our Sun has. They must, therefore, have either a less density or a greater surface brilliancy. . . . Many of them are probably even less dense than air, and in nearly all cases the density is far less than that of any known liquid."

It follows that at least the brighter stars are masses of gas, more or less compressed in their interior by the action of gravitation upon their more superficial parts.

"This conclusion was arrived at, at least in the case of the Sun, from different considerations before the spectroscope had taught us anything of the constitution of the bodies.

SOURCE OF THE SUN'S HEAT.

It is accepted that for untold millions of years, the Sun has been radiating heat into space, and the problem has been to discover the source of the heat. In the time of KANT, NEWTON, LAPLACE, and HERSCHEL, no reason was known why the stars should not shine on forever without change. Now that heat has been determined as a form of energy, the supply of which is limited, it becomes a question as to the source of supply. If the Sun, composed, as it is known to be, of the same material as the Earth, kept on radiating its heat as it does without a source of supply, it would cool off at the rate of from 5° to 10° a year. The theory of meteors falling to the Sun was advanced, but this has been abandoned for the theory of KELVIN and HELMHOLTZ, that the source of the heat is the contraction of the material of the Sun, calculated as 200 feet a year, or four miles in a century. From this it follows that the Sun must be a gas, for

> "if solid, the exterior would rapidly cool off, since the heat would have to be conducted from the interior. Then, the loss of heat no longer going on at the same rate, the contraction also would stop and the generation of heat to supply the radiation would cease. Even were the Sun a liquid, currents of liquid matter could scarcely convey to the surface a sufficient amount of heated matter to supply the enormous radiation."

The fact that the Sun remains gaseous at the extreme density, more than that of water, is explained by the compression of the interior by the weight of the outside portions.

The theory developed by RITTER regarding the source of heat being due to the contraction of the volume of the Sun has for a basis the paradoxical law announced by LANE, that

> "When a spherical mass of incandescent gas contracts through the loss of its heat by radiation into space, its temperature continually becomes higher as long as the gaseous condition is retained."

STELLAR EVOLUTION.

On this is based the theory of stellar evolution. We may start with the nebulæ, when, by some progressive change, they began to shine. This is the unsolvable question: How did they begin? The gradual contraction under gravity resulted in a gaseous body of a higher temperature. It is thus possible to speak of the age of a star, meaning periods measured by tens of millions or hundreds of millions of years. Sir WILLIAM HUGGINS gives the series of ages based on the color of light emitted, which starting with bluish-white at the first stage, passes on through white into yellow and red. The series is as follows:—

Sirius, α *Lyræ*.
α *Ursæ Majoris*.
α *Virginis*.
α *Aquilæ*.
Rigel.
α *Cygni*.
Capella — The Sun.
Arcturus.
Aldebaran.
α *Orionis*.

A question of interest is, At what stage will the temperature reach its maximum? It is impossible to give a precise answer, but "it seems probable that the highest temperature is reached in about the stage of our Sun."

While the indications point to the truth of this theory,

"Yet there are some unsolved mysteries connected with the case, which might justify a waiting for further evidence, coupled with a certain degree of skepticism."

The nebulæ offer a difficulty. Their extreme tenuity and their seemingly almost immaterial structure appear inadequate to account for any such mutual gravitation of their parts as would result in the generation of the flood of energy they are constantly radiating. We must therefore suggest at least the possibility that all shining heavenly bodies have connected with them some form of energy of which science can, as yet, render no account."

STRUCTURE OF THE STELLAR UNIVERSE.

From the discussion of the origin of the stellar universe, Professor NEWCOMB passes to its structure.

"The problem of the structure and duration of the universe is the most far-reaching with which the mind has to deal. Its solution may be regarded as the ultimate object of stellar astronomy. . . . Although we can attack the problem to-day by scientific methods, to a limited extent, it must be admitted that we have scarcely taken more than the first step toward the actual solution.

"Firstly, we may inquire as to the extent of the universe of stars. Are the latter scattered through infinite space, so that those we see are merely that portion of an infinite collection which happens to be within reach of our telescopes, or are all the stars contained within a certain limited space? In the latter case, have our telescopes yet penetrated to the boundary in any direction?

"Secondly, granting the universe to be finite, what is the arrangement of the stars in space? In what sense, if any, can the stars be said to form a permanent system? Do the stars which form the Milky Way belong to a different system from the other stars, or are the latter a part of one universal system?

"Thirdly, what is the duration of the universe in time? Is it fitted to last forever in its present form, or does it contain within itself the seeds of dissolution? Must it, in the course of time, in we know not how many millions of ages, be transformed into something very different from what it now is?"

The first and third propositions were, according to KANT, equally susceptible of proof or disproof from *à priori* reasoning. The scientific man objects to this conclusion, as the propositions are matters of fact. The more correct view is that of Sir WILLIAM HAMILTON, that the conception of infinite space or time, or the coming to an end of space or time, is impossible for us to hold, the deficiency being due to our mental limitations. So this gives us no clew to the actual universe. Our conclusions must be based on actual observation.

EXTENT OF THE UNIVERSE.

There is a law of optics which throws some light on the question of the extent of the universe. If we assume the stars uniformly distributed throughout space and conceive a number of spherical shells, one outside of another, extended indefinitely, then the number of stars in each spherical shell would be proportional to the square of the radius of the given shell. But the light from the shells varies inversely as the square of the distance from the center where the observer is; therefore each successive shell would send equal amounts of light to the center. In this case if the universe was indefinitely extended, the "heavens would be filled with a blaze of light as bright as the Sun."

"But there are two limitations to this conclusion. It rests upon the hypothesis that light is never lost in its passage to any distance however great. This hypothesis is in accordance with our modern theories of physics, yet it cannot be regarded as an established fact for all space, even if it be true for the distances of the visible stars."

Again, an infinite universe could be imagined on the hypothesis of LAMBERT. A number of groups like the solar form a greater system, and a number of these systems form the Galaxy.

"But modern developments show that there is no scientific basis for this conception, attractive though it is by its grandeur."

"So far as our present light goes, we must conclude that, although we are unable to set absolute bounds to the universe, yet the great mass of stars is included within a limited space, of whose extent we have as yet no evidence. Outside of this space there may be scattered stars or invisible systems. But if these systems exist, they are distinct from our own."

THE ARRANGEMENT OF THE STARS IN SPACE.

"The second question, that of the arrangement of the stars in space, is one on which it is equally difficult to propound a definite general conclu-

sion. . . . Sir William Herschel reached the conclusion that our universe was a comparatively thin but widely extended stratum of stars. But we cannot assume that this hypothesis of the form of the universe affords the basis for a satisfactory conception of the arrangement."

The Milky Way would be uniformly illumined, but it is not, being a chain of irregular, cloudlike aggregations of stars. Professor NEWCOMB then enters into a discussion of the appearance of a universe of stars in the form of a circular disc as seen from different directions. Following this is a summary of observed data bearing on the distribution of the stars, the results of which are as follows. The lucid stars increase in density toward the Milky Way, so that if

"the cloudlike forms which make up the Milky Way were invisible to us, we should still be able to mark its course by the condensation of the brighter stars."

Of the fainter stars,—

"the star density in the several regions increases continuously from each pole to the Galaxy itself. . . . The conclusion to be drawn is a fundamental one. The universe, or, at least, the denser portions of it, is really flattened between the galactic poles, as supposed by Herschel and Struve."

As to those stars having a proper motion, the following is advanced:—

"Having found that the stars of every magnitude have a tendency to crowd toward the region of the Milky Way, the question arises whether this is true of those stars which have a sensible proper motion. Kapteyn has examined this question in the case of the Bradley stars. His conclusion is that those having a considerable proper motion, say more than ten seconds per century, are nearly equally distributed over the sky, but that when we include those having a small proper motion, we see a continually increasing tendency to crowd toward the galactic plane. The conclusion is interesting and important. If we should blot out from the sky all the stars having no proper motion large enough to be detected, we should find remaining stars of all magnitudes; but they would be scattered almost uniformly over the sky, and show no tendency toward the Galaxy."

"From this it again follows that the stars belonging to the Galaxy lie farther away than those whose proper motions can be detected."

A study of the heavens will soon show that there is a tendency for the bright lucid stars to form groups, instances of which are the *Pleiades*, *Præsepe*, and *Orion*.

"The question we now propose to consider is whether these clusters include within their limits an important number of the small stars seen in the same direction. If they and all the small stars which they con-

tain within their actual limits were removed from the sky, would important gaps be left? The significance of this question will be readily seen. If important gaps would be left, it would follow that a large proportion of the stars which we see in the direction of the clusters really belong to the latter, and that, therefore, most of the stars would be contained within a limited region."

After a numerical examination of the number of stars within the groups mentioned above, the conclusion is that

"the agglomeration of the lucid stars into clusters does not, in the cases where it is noticeable to the eye, extend to the fainter stars."

A study of the regions relatively poor in lucid stars leads to the same conclusion.

THE MILKY WAY.

Passing now to the structure of the Milky Way, Professor NEWCOMB gives a detailed description of the wonderful object as seen by an observer at different times of the year. One of the first noted facts is the inequalities of structure, which are noticeable to the eye.

"The Milky Way is something more than the result of the general tendency of the stars to increase in number as we approach its central line. There must be large local aggregations of stars, because, as we have already pointed out, there cannot be such diversity of structure shown in a view of a very widely stretched stratum of stars. . . . The fundamental question we meet in our further study of this subject is: At what magnitude do these agglomerations of stars begin? Admitting, as we must, that they are local, are they composed altogether of stars so distant as to be faint, or do they include stars of considerable brightness?"

A method of counting the stars in the regions in question, is followed, and

"The conclusion is that an important fraction of the lucid stars which we see in the same areas with the agglomerations of the Milky Way is really in those agglomerations and forms part of them."

The darker regions of the Milky Way are also found to contain as many stars as there are in the regions immediately on each side of the galactic belt. The evidence is that

"separate from the accumulations of stars in the Milky Way, perhaps extending beyond them, there is a vast collection of scattered stars, spread out in the direction of the galactic plane, which fill the celestial spaces in every direction. We have shown that when, from any one area of the sky, we abstract the stars contained in clusters, this great mass is not seriously diminished. We have also collected evidence that the distances of this great mass are very unequal; in other words, there is no great accumulation, in a superficial layer, at some one distance. . . .

Our general conclusion is this: If we remove from the sky all the local aggregations of stars, and also the entire collection which forms the Milky Way, we should have left a scattered collection, constantly increasing in density toward the galactic belt."

Another interesting point to be considered is the increasing number of stars with diminishing brightness. The number of stars in each succeeding order of magnitude is between three and four times as great as in the preceding one. Using only rough approximations, the amount of light received will be about doubled for a change of two units of magnitude, the stars of lower magnitude, though fainter individually, being greater in number, collectively give more light. A careful summary of the star catalogues leads to the general conclusion that

"up to the eleventh magnitude there is no marked falling off in the ratio of increase, even near the poles of the Galaxy."

The question when the series begins to fall away is, therefore, still an undecided one. If there be no diminution of light due to distance, then the number of stars must begin to decrease at some point, or the sky would be filled with a blaze of light.

"From what has been shown of the total amount of light received from stars of the smaller magnitudes, it would seem certain that a considerable fraction of the apparently smooth and uniform light of the sky may come from these countless telescopic stars, even perhaps from those which are not found on the most delicate photographs."

The chapter following is devoted to a statistical study of the proper motions of the stars. Space will not permit us to follow Professor NEWCOMB in his argument on this subject. His general conclusion, which he says is in good agreement with that arrived at by Professor KAPTEYN by a different method, is that the average actual motion of a star in space is about 37 kilometers per second. The motion of Sun is given as 20 kilometers. The Sun is therefore a star of quite small proper motion.

DISTRIBUTION OF THE STARS IN SPACE.

In the final chapter, on the distribution of the stars in space, the lines of thought set forth in the former chapters are made to converge on that main and concluding problem. With our system as a center, the celestial space is supposed divided into concentric shells, the radius of the first inside sphere being equal to 206.265 times the orbit of the Earth, or a distance at which the parallax of a star would be 1". The succeeding shells have radii of 2 R, 3 R, etc., and the parallaxes of the stars on the surface would be respectively 0″.5, 0″.33, 0″.25, etc. In the first sphere, since no star has been found with a parallax of 1″, the Sun would be alone. Continuing, a list is given of the stars whose parallax is known, and the result is that in the second sphere there would be one star to seven units of space of the cube of R. The outer regions give the ratio of one in twelve. Considering the first result, there would be one star in a sphere of radius R, or diameter 412,500 times the Earth's orbit. Light traveling over 180,000 miles a second would thus pass a star every eight and a half years. A study of the large and small proper motions leads to about the same conclusion, or one star to eight units of space of the cube of R. By a study of the stars with a cross motion of less than 2″.5 per century, it is concluded that the sphere of lucid stars extends much beyond 400 R.

> "Granting the star density as we have supposed, a sphere of radius 400 R would contain 8,000,000 stars. As we see more than this number with our telescope, we have no reason to suppose the boundary of the stellar system, if boundary it has, to be anywhere near this limit."

> "All the facts we have collected lead to the belief that, out to a certain distance, the stars are scattered without any great and well-marked deviation from uniformity. But the phenomena of the Milky Way show that there is a distance at which this ceases to be true. . . . Can we form any idea where this difference begins, or what is the nearest sphere which will contain an important number of galactic stars? A precise idea, no; a vague one, yes. We have seen that the galactic agglomerations contain quite a number of lucid stars, and that, perhaps, an eighth of these stars are outside the sphere 400 R. We may, therefore, infer that the Milky Way stars lie not immensely outside this sphere. More than this, it does not seem possible to say at present."

It is probable that we lie near the center of the stellar universe. The equality of the stars on both sides of the galactic circle and the fact that the galactic circle is a great circle are offered as proof. This merely proves that we lie in the galactic plane. The evidence as to our lying near the center is not so conclusive, and not until the international photographic survey of the heavens is completed does it seem possible to reach a more definite conclusion.

Inspired by that spirit of caution which characterizes the entire series of chapters when dealing with conclusions not entirely supported by facts, Professor NEWCOMB closes thus:—

> "One reflection may occur to the thinking reader as he sees the reasons for deeming our position in the universe to be the central one. PTOLEMY showed by evidence, which, from his standpoint, looked as sound as that we have cited, that the Earth was fixed in the center of the universe. May we not be the victims of some fallacy, as he was?"

SUN-SPOTS.

By Rose O'Halloran.

Viewed through a four-inch telescope, the surface of the Sun has been as unspotted as untrodden snow for months past.

At length, on the 19th of May, at 11 A.M., a sizable spot in two sections was discerned about twenty degrees inside the northeast limb. In that position some are very distinct, but this had a penumbral aspect, as if the solar atmosphere were very dense. The day following was cloudy; but on the 21st instant, at 9 A.M., in the less foreshortened view, it proved to be a group with three umbræ, one rather large in the foremost section, and two smaller ones in the more easterly section. The adjacent penumbra had commenced to branch northward a few hours afterwards, and on the following morning had developed a distinct umbra, while the two umbræ south of it were transformed into a curving row of five umbræ. On May 23d numerous changes were apparent. The large umbra of the foremost spot was divided, or "bridged," as it is called when a streak of white photospheric matter crosses a dark tract. The new northward umbra of the other section was arching in form, and the last two of the curving row had drifted forward under the three, which in the mean time had united into a dark streak.

The faint penumbral filaments connecting the two divisions had disappeared, and each of the separated tracts had well-defined breaks crosswise where there seemed to be no penumbral matter. The best measurement of position was obtained on the 24th instant, at 11 A.M., as the group was near the center of the disc, and the solar axis corresponded with the meridian. The entire group, which was fully 72,000 miles in length, and elongated in a nearly east-and-west direction, was about eight degrees north of the solar equator.

The foremost umbra was again bridged, the other umbræ were so altered as to form and position as to be scarcely identifiable, and a general shrinkage had evidently set in. On the 25th and 26th instants it was seen only imperfectly through a layer of cloud. On May 27th, 9:45 A.M., the foremost umbra had undergone some changes, as if a part had drifted in advance, and instead of being elongated north and south, it extended in an east-and-west direction. This umbra was in three distinct parts at 11:30 A.M. on May 28th, and the entire formation seemed to be still diminishing.

The general outlines seemed unchanged at 1 P.M. May 29th, but the division in the larger umbra was undiscernible, perhaps on account of the foreshortened view and the solar atmosphere. On May 30th the outlines were still visible near the limbs, but on the 31st it had passed from view. At the present stage of sunspot minimum the details of a group of more than average size have especial interest, as the known irregularities of the cycle make it possible that they may be the initial footprints of a returning maximum.

SAN FRANCISCO, May 31, 1901.

FLUCTUATIONS OF *NOVA PERSEI.*

BY ROSE O'HALLORAN.

Nova Persei was observed on about fifty clear evenings between 7:30 and 9:00, P. S. T., commencing on February 24th, and ending in the beginning of May. During this period its decline from 1st magnitude to 6.5 was interrupted by nine temporary revivals of light, which were estimated as follows, with the aid of the charts published by Father HAGEN:—

Between February 28th and March 2d, from 2.1 to 1.9 mag.
Between March 11th and 12th, from 3.3 to 3.1 mag.
Between March 20th and 27th one or two fluctuations were noticed, but not having been recorded at the time of observation, the amount of increase or the dates could not be recalled accurately.
Between April 7th and 8th, from 5.2 to 4.6 mag.
Between April 10th and 12th, from 5.4 to 4.6 mag.
Between April 16th and 18th, from 5.6 to 4.2 mag.
Between April 22d and 23d, from 6.5 to 4.0 mag.
Between April 26th and 27th, from 6.0 to 4.5 mag.
Between April 27th and May 6th, from 6.0 to 4.0 mag.

This last estimate of increase was unsatisfactory on account of the interference of high buildings, which hindered further observation afterwards. The intervals in which fluctuations occurred sometimes included cloudy days, so that the dates of increase are those on which the change was first detected at its highest stage. The greatest decline of the *Nova* was to 6.5 magnitude, on the 22d of April.

San Francisco, May 31, 1901.

COMET HOLK.

By Edgar L. Larkin.

The Australian comet, discovered by Holk, April 23d, was well observed at the Mount Lowe Observatory to-night, May 17, 1901, at $7^h\ 38^m$. Its approximate position then was:—

$$\alpha \quad 5^h\ 50^m\ 30^s$$
$$\delta \quad +4^\circ\ 46'$$

The nucleus was small, but bright and distinct in the brilliant twilight, and had the appearance, nearly as could be judged, of a 4th-magnitude, orange-colored star. The tail was about five minutes in length and quite wide. A fog has rested upon the summits of Tujunga and Verdugo Mountains for six days. These ranges constitute the western horizon here, and the comet could not have been seen before. Professor Kreutz's ephemeris was used. The visitor was seen at $7^h\ 38^m$, and disappeared behind the peaks at $8^h\ 13^m$, thus affording only thirty-five minutes for observation. The tail was so faint that it could not be seen in the high power of the micrometer, so it was not measured,— the apparent length being an estimate with low power, 132 Gundlach periscopic. No attempt was made to secure a spectrum, owing to the short time available, and it is doubtful if a spectrum could have been seen in the twilight glow, and still more a subject of doubt whether it would possess value if obtained, owing to vapors round about the mountain tops.

The comet's motion was rapid and could be easily seen in the short time the display was on. There were no catalogue-stars in field. If the comet had been at high altitude, it is probable that the tail would have been as much as one degree in length. The celestial wanderer was almost invisible in the finder, but the nucleus was clearly seen in the 16-inch, while the tail was brighter than thought possible in the glimmer of solar rays and the glow of the Zodiacal Light. And this glowing cone of light is far more brilliant here than at any observatory in the Eastern States.

Altogether the observation seems to have been quite satisfactory under the existing conditions.

MOUNT LOWE (CAL.) OBSERVATORY, May 17, 1901.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1901.

By MALCOLM MCNEILL.

JULY.

The Earth is in aphelion July 4, 8 A.M. P. S. T.

Mercury is an evening star at the beginning of the month, too near the Sun to be seen. It rapidly approaches the Sun, passes inferior conjunction on the morning of July 13th, and then rapidly recedes from the Sun. It may be seen as a morning star during the last few days of the month in the early twilight.

Venus is gradually increasing its distance from the Sun, and is beginning to be conspicuous as an evening star. During most of the month it sets rather more than an hour after sunset. It moves about 40° east and 11° south through *Cancer* into *Leo*. On July 28th it passes about 1° north of *Regulus*.

Mars is in the western sky in the evening, setting a little before 10 P.M. at the end of the month. Its rate of recession from the Earth is still over twenty millions of miles per month, and on July 31st its distance from us is about one hundred and sixty-three millions of miles. Its apparent motion among the stars is 16° east and 7° south from *Leo* into *Virgo*. On the evening of July 6th it passes very close, less than 20′, south of the fifth-magnitude star β *Virginis*.

Jupiter and *Saturn* are still close together in *Sagittarius*, and as they are both near opposition, they are above the horizon practically the entire night. *Jupiter* was in opposition on June 30th, and *Saturn* will be in opposition on July 5th. Both are moving westward. *Jupiter* not quite 4° and *Saturn* rather more than 2°, and at the end of the month are about 7° apart, *Jupiter* being west of *Saturn*.

Uranus is about two hours' motion west of *Saturn*, and sets two hours earlier. It is still in the southern extension of *Ophiuchus*, and moves about 1° westward during the month. There is no bright star near it to mark its position, but at the beginning of the month it is about half a degree north of the sixth-magnitude star *24 Ophiuchi.* Its motion during the month carries it away from the star.

Neptune is a morning star too near the Sun for good observation.

AUGUST.

Mercury is a morning star at the beginning of the month, passing greatest west elongation on the morning of August 2d. It then rises about an hour and a half before sunrise, and the interval is more than an hour until about the middle of the month. After that the planet rapidly approaches the Sun and passes superior conjunction on the afternoon of August 27th.

Venus is an evening star, setting rather more than an hour after sunset throughout the month. It increases its apparent distance from the Sun from 25° to 32°, but at the same time the planet draws more and more south from the Sun, so that the interval between the settings of the Sun and planet remains practically the same. The planet moves 33° east and 15° south during the month, going from *Leo* into *Virgo.*

Mars, at the beginning of the month, is in just about the position *Venus* will occupy at the end. Its rate of recession from the Earth is not quite as great as for two or three months past, being only fourteen millions of miles. On August 31st it is not quite twice the mean distance of the Earth from the Sun distant from us. It has ceased to be a conspicuous object, but will still be about as bright as the standard first-magnitude star. It moves through the constellation *Virgo* 18° east and 7° south. On August 18th it passes about 2° north of the first-magnitude star *Spica*, *α Virginis.* Its brightness will then differ little from that of the star, but its ruddy color will make it readily distinguishable.

Jupiter and *Saturn* still keep their positions in *Sagittarius* north of the group called the "Little Dipper." They are setting earlier, and by the end of the month do not remain above the horizon much after midnight. They still keep up their retrograde motion toward the west, but more slowly than before; and *Jupiter* becomes stationary just before the end of the month, while *Saturn* does not reach his turning-point until a fortnight later. Their distance apart remains pretty constantly a little more than 7°, and each moves about a degree and a half westward among the stars.

Uranus sets about two hours earlier than during July. It retrogrades slowly until August 22d, when it becomes stationary, and then begins its eastward motion.

Neptune is a morning star, but by the end of the month rises a little after midnight.

Look out for meteors during the middle of the month, more especially the nights from August 11th to 13th. This shower, which comes yearly, radiates from the constellation *Perseus*. This rises in the northeast in the early evenings. More meteors are likely to be seen after midnight than before.

JULY–AUGUST, 1901.

PHASES OF THE MOON, P. S. T.

Full Moon . . .	July 1,	3^h 18^m	P. M.
Last Quarter . . .	July 8,	7 20	
New Moon . . .	July 15,	2 10	A. M.
First Quarter . . .	July 23,	5 58	
Full Moon . . .	July 31,	2 34	
Last Quarter . . .	Aug. 7,	12 2	
New Moon . . .	Aug. 14,	12 27	
First Quarter . . .	Aug. 21,	11 52	P. M.
Full Moon . . .	Aug. 29,	12 21	

THE SUN.

1901.	R. A.	Declination.	Rises.	Transits.	Sets.
July 1,	6^h 39^m	+23° 9′	4^h 39^m A.M.	12^h 3^m P.M.	7^h 27^m P.M.
11,	7 20	+22 11	4 46	12 5	7 26
21,	8 0	+20 34	4 53	12 6	7 19
Aug. 1,	8 44	+18 9	5 3	12 6	7 9
11,	9 22	+15 25	5 11	12 5	6 59
21,	10 0	+12 17	5 21	12 3	6 45
31,	10 36	+ 8 49	5 30	noon	6 30

MERCURY.

July 1,	7 50	+18 25	6 9 A.M.	1 14 P. M.	8 19 P.M.
11,	7 31	+17 6	5 17	12 16	7 15
21,	7 10	+18 0	4 12	11 15 A.M.	6 18
Aug. 1,	7 22	+20 3	3 34	10 45	5 56
11,	8 18	+20 3	3 50	11 1	6 12
21,	9 36	+16 2	4 44	11 40	6 36
31,	10 52	+ 9 0	5 45	12 16 P. M.	6 47

VENUS.

1901.		R. A.	Declination.	Rises.	Transits.	Sets.
July	1,	7 51	+22 22	5 54 A.M.	1 15 P.M.	8 36 P. M.
	11,	8 42	+19 49	6 17	1 27	8 37
	21,	9 31	+16 20	6 40	1 37	8 34
Aug.	1,	10 23	+11 42	7 6	1 46	8 26
	11,	11 8	+ 6 56	7 27	1 51	8 15
	21,	11 53	+ 1 53	7 49	1 56	8 3
	31,	12 36	− 3 17	8 11	2 0	7 49

MARS.

July	1,	11 36	+ 3 15	10 48 A.M.	5 0 P.M.	11 12 P.M
	11,	11 56	+ 0 54	10 38	4 41	10 44
	21,	12 17	− 1 32	10 27	4 22	10 17
Aug.	1,	12 40	− 4 15	10 16	4 2	9 48
	11,	13 3	− 6 46	10 8	3 45	9 22
	21,	13 26	− 9 16	10 1	3 29	8 57
	31,	13 51	− 11 44	9 54	3 14	8 34

JUPITER.

July	1,	18 35	−23 10	7 26 P.M.	12 2 A.M.	4 38 A.M.
Aug.	1,	18 20	−23 25	5 5	9 40 P. M.	2 15
Sept.	1,	18 14	−23 31	2 59	7 33	12 7

SATURN.

July	1,	18 58	−22 18	7 45 P.M.	12 25 A.M.	5 5 A.M
Aug.	1,	18 49	−22 33	5 30	10 9 P.M.	2 48
Sept.	1,	18 43	−22 43	3 24	8 2	12 40

URANUS.

July	1,	16 50	− 22 30	5 35 P.M.	10 14 P.M.	2 53 A.M
Aug.	1,	16 47	− 22 24	3 29	8 8	12 47
Sept.	1,	16 46	− 22 23	1 26	6 5	10 44

NEPTUNE.

July	1,	5 57	+22 18	4 2 A.M.	11 22 A.M.	6 42 P.M.
Aug.	1,	6 2	+22 18	2 4	9 24	4 44
Sept.	1,	6 5	+22 17	12 6	7 26	2 46

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

II,	R,	July	2,	9^{h}	13^{m}	P. M.	II,	R,	Aug.	3,	8^{h}	57^{m}	P. M.
I,	R,		5,	2	37	A. M.	III,	D,		4,	9	37	
I,	R,		6,	9	6	P. M.	III,	R,		5,	12	37	A. M.
IV,	R,		7,	12	51	A. M.	I,	R,		5,	11	13	P. M.
II,	R,		9,	11	49	P. M.	I,	R,		7,	5	42	
I,	R,		12,	4	32	A. M.	II,	R,		10,	11	34	
I,	R,		13,	11	0	P. M.	III,	D,		12,	1	37	A. M.
I,	R,		15,	5	29		I,	R,		13,	1	8	
II,	R,		17,	2	25	A. M.	I,	R,		14,	7	37	P. M.
I,	R,		21,	12	55		I,	R,		21,	9	32	
I,	R,		22,	7	24	P. M.	I;	R,		23,	4	0	
IV,	D,		23,	4	38		II,	R,		28,	6	8	
IV,	R,		23,	7	3		I,	R,		28,	11	27	
II,	R,		27,	6	20		I,	R,		30,	5	55	
III,	R,		28,	8	36								
I,	R,		29,	9	18								

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

MAGNITUDE ESTIMATES OF *NOVA PERSEI.*

Estimates of the brightness of the new star in *Perseus* have been made as regularly as possible since February 24th, when news of its discovery was received.

These estimates at first were made without any instrumental aid, by comparing the star with *Capella* α, ϵ, δ, ν, κ *Persei*. As the star's light faded, opera-glasses, and later the 3-inch finder of the 12-inch telescope, and still later the 12-inch telescope itself, were used, comparisons being made with the stars ψ, σ, *l Persei*, and with BD + 43°.674, BD + 45°.778, BD + 44°.734; the magnitudes of the comparison stars being taken from HAGEN'S Chart I.

The observations show that the light of the *Nova*, while it has been fading, has been subject to marked fluctuations almost from the beginning — a fact that is abundantly confirmed by observers elsewhere. But no definite period of variation can be satisfactorily established from the observations made here, nor yet by combining with them those made at other places so far as these have been published.

The following table gives the magnitudes of the new star derived from my observations:—

1901.	P. S. T.		1901	P. S. T.	
	h	m		h	m
Feb. 24	8	0.5	Mar. 12	9	3:5
25	1	1.0	13	9	3:7
25	6:30	0.9	14	7—10	3:5
26	7:30	1.4	15	8	3:8
27	7	2.0	16	8	3:9
28	10	2.0	17	8—10	3:9
Mar. 1	8	2:4	18	8	4.0
2	7	2:4	19	7—9	4.1
3	7	2:5	20	7:30	4.5
4	8:20	2:5	22	8	4.7
5	7—10	2:7	23	7	4.0
6	7—10	3:0	28	8	4.7
8	7	3:2	28	10	5.0

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* Lick Astronomical Department of the University of California.

1901	P. S. T.		1901	P. S. T.	
	h	m		h	m
Mar. 29	9	5.0	Apr. 23	7:30—9:30	4.5
31	9	4.7	25	8	5.3
Apr. 1	9:30	4.5	26	8:30—9	5.4
4	7:30	4.2	May 2	8:45	4.7
5	8	4.7	3	8:15	5.4
6	8	5.0	4	8:30	6.0
7	8	5.4	5	8	6.0
8	9	4.2	6	8	5.8
9	8	5.0	7	8	4.4
10	9	5.5	8	8	5.3
11	8—10	5.7	9	8	5.8
13	7:30	6.0	10	8	6.0
14	8	6.1	11	7:50	6.0
15	8	6.1—6.2	12	8:30	5.7
16	8	6.0—6.1	13	8:15	5.5
17	7:30	4.4	14	8.20	5.7
19	8	5.5	15	8:25	6.0
20	8	6.2	16	8	5.8
21	8	5.6	17	7:50	4.7—4.8
22	8:30	4.7	19	8	6.0—6.2

May 22, 1901. R. G. AITKEN.

NOTE ON COMET *a* 1901.

This comet was discovered independently at several stations in the southern hemisphere, and for a time was to southern observers a conspicuous object in the morning and later on in the evening sky.

Because of its position south of the Sun, it could not be seen at northern observatories during its period of greatest brightness. It was looked for here carefully on every clear evening and morning from April 26th, the date of the announcement of its discovery, until May 3d, when the cablegram from Arequipa showed that it had passed the Sun and become an evening object. The evening sky was then searched without success until Tuesday, May 14th, when in the strong twilight it was seen as a hazy star of about the eighth magnitude in R. A. $5^h\ 33^m$; Decl. $+ 3^{\circ}\ 34'$. This seems to have been the first observation made of the comet in the northern hemisphere.

Accurate observations secured on the evenings of May 15th and 16th, showed that it was a little behind the position predicted by Dr. KREUTZ's preliminary orbit, and that it was fading quite rapidly. On the latter date two stars, called 8.2 and 8.7 magnitude respectively in the Albany A. G. Catalogue, were in the telescope-field with the comet; the one was certainly brighter, the other fainter, than the comet. Last night, May 21st, it was fainter than a star of ninth magnitude,— too faint for accurate measures in the twilight and haze. R. G. AITKEN.

May 22, 1901.

MEASURES OF δ *EQUULEI*, = OΣ 535.

Unfavorable weather prevented observations of this interesting binary until the morning of May 3d (astronomical date). It was then distinctly elongated, and a measure was secured without much difficulty. Another measure was made on the following morning under somewhat less favorable conditions, though the elongation was unmistakable. The distance measured in a pair of this kind is likely to be the longer diameter of the image, rather than the actual distance between the centers of the two components, unless the observing conditions are ideal. My estimates of distance on both nights, based on the thickness of the micrometer wires, was $\frac{1}{10}''$ or a very little more.

The measures are:

	θ	ρ	wt.
1901.337	201°.5	0″.13	4.
1901.340	200 .3	0 .16	3.

The quadrant is wholly indeterminate. I have taken the third quadrant for the purpose of comparison with Professor HUSSEY'S ephemeris (No. 76, p. 223, these *Publications*), which gives for 1901.338 192°.0 0″.10.

R. G. AITKEN.

MEASURES OF THE COMPANIONS TO *SIRIUS* AND *PROCYON*.

Sirius.

1901.165	135°.7	4″.97	3	36
.277	134 .4	5 .18	4	36
.296	135 .0	5 .25	4	36
1901.25	135°.0	5″.13		

Procyon.

1901.154	337°.1	″	3	36
.156	338 .6	5 .23	3	36
.299	339 .9	5 .05	3	36
1901.20	338°.5	5″.13		

The last two measures of *Sirius* were made in strong twilight. The seeing then was excellent, so that a thousand-power eyepiece could be used and the companion could be seen steadily during the whole time of observation. The good seeing lasted only a short time, however, and *Procyon* could not be measured on either night. The companion to the latter star is now much harder to see than the companion to *Sirius*, and the measures, especially of distance, are subject to much larger probable error.

ZWIERS's ephemeris gives for *Sirius*:—

1901.25 133°.3 5".07.

R. G. AITKEN.

May 8, 1901.

THE DEATH OF PROFESSOR ROWLAND.

The physical side of Astronomy suffered a great loss on April 16th, in the death of Professor HENRY A. ROWLAND, of Johns Hopkins University, in the fifty-third year of his age. Professor ROWLAND occupied the Chair of Physics from 1876, the date of the opening of the university, until the time of his death.

Professor ROWLAND'S contributions to our knowledge of heat, electricity, and light earned for him a place in the front rank of the physicists of the world. Astronomy is indebted to him mainly for the perfection of the diffraction-grating and for his studies on the grating spectrum of the Sun. His tables of wave-lengths in the solar spectrum are so generally in use that they may be said to form the basis of all accurate astronomical spectroscopy. His premature death has given rise to heartfelt expressions of regret from the entire scientific world.

W. W. C.

THE LICK OBSERVATORY BULLETIN.

Early in the present year the Lick Observatory began to issue a bulletin to supply a want long felt. Its purpose was to furnish a medium of publication insuring prompt distribution of important results, and likewise that it should be used for publishing long and technical articles unsuitable for journal publication, and which could not await publication in volume form.

It is not intended that the mailing-list shall include individuals except in the rare cases where investigators have not ready access to the *Bulletin* through institutions.

Bulletins Nos. 1 and No. 2 have been issued. They contain Professor TUCKER'S meridian-circle positions of the comparison-stars to be used as a basis for determining the solar parallax, from observations of the planet *Eros*. The total number of stars observed by Professor TUCKER is 677. The total number of observations required was slightly over 2,000, including circumpolars and nadirs.

The materials for a number of other Bulletins are at hand, and they will be issued in the near future. W. W. CAMPBELL.

VISUAL OBSERVATIONS OF *NOVA AURIGÆ*.

It is stated in the *Observatory* for March, 1901, (p. 127,) that ANDERSON'S new star of 1892 in *Auriga* "has not been seen for many years"; a statement perhaps implying, from its context, that *Nova Auriga* has been invisible.

This star was looked for by Mr. AITKEN and myself with the 36-inch refractor on the evening of April 4, 1901, and was found without difficulty, though the sky was hazy and strongly illumined by the full moon. The *Nova* was fainter by 0.2 magnitude than BURNHAM'S comparison-star I (chart in *Mon. Not.*, R. A. S. for April, 1892,) and considerably brighter than comparison-star J. Its magnitude was estimated to lie at one fourth the distance from that of I to that of J. That is, the *Nova* was estimated to be of the 12th magnitude on BURNHAM'S scale.

The same peculiarities of focus existed as in previous years; and no doubt the spectrum is still nebular. No opportunity was available for making direct spectroscopic observations.

My last previous observation was in August, 1898, when *Nova Auriga* was of the 11th magnitude.

The brightness of the *Nova* at its second discovery, in August, 1892, was 10.5 magnitude. W. W. CAMPBELL.

THE CROCKER ECLIPSE EXPEDITION TO SUMATRA.

The Crocker Eclipse Expedition from the Lick Observatory to Sumatra, in charge of Acting Astronomer C. D. PERRINE, arrived at Padang on April 5th, with the instruments and other freight in good condition. After a preliminary survey of the surrounding country, Professor PERRINE decided to locate the observing-station on the plains rather than in the mountains, as, from his own observations and from the experience of scientific residents of Padang, the cloud conditions were considered more favorable at the lower altitudes. The station was located just outside the northern edge of the city, on the abandoned racetrack. Preparations for mounting and adjusting the instruments were proceeded with rapidly, and volunteer observers were arranged for shortly after the arrival of the party. No doubt Professor PERRINE had the instruments in complete preparation and the assistants thoroughly drilled by the time of the eclipse.

A cablegram received at the Lick Observatory on May 18th stated that at the time of totality considerable interference from clouds was experienced; but the hope was expressed that useful results had been obtained. A later cablegram, on May 24th, presumably after the photographic plates had been developed, contained the gratifying information that some results had been obtained with all the instruments. No doubt the exposures of the photographic plates were madc according to programme; and the natural interpretation of the two cablegrams is that the successful photographs were obtained in the intervals between clouds floating over the Sun.

Further information concerning the details of the results is not expected until about July 10th, when Professor PERRINE'S letters will probably arrive.

Inasmuch as this eclipse was of unusually long duration, it is hoped that the results will compare in quantity and quality very favorably with those secured at the eclipses of short duration in 1898 and 1900. W. W. CAMPBELL.

ASTRONOMICAL TELEGRAMS.

(Translations.)

CAMBRIDGE, MASS., Apr. 26, 1901.

To Lick Observatory: (Received 1:00 P.M.)

Kiel cables that a very bright comet was discovered by HALLS at Queenstown, April 23; it was observed at the Cape of Good Hope on April 24.712 Greenwich M. T. in R. A. $1^h\ 30^m\ 4^s$; Declination $+ 3^\circ\ 27'$; approximate observation, sent by GILL.

(Signed) EDWARD C. PICKERING.

BOSTON, Mass., May 3, 1901.

To Lick Observatory: (Received 1:40 P.M.)

Arequipa cables a very bright comet seen in R. A. $3^h\ 30^m$; Declination south 1°. Probably Thursday morning.

(Signed) JOHN RITCHIE, JR.

[A letter received later from Harvard College Observatory indicates that the comet was seen at Arequipa on the evening of Thursday, May 2, at $11^h\ 35^m$ G. M. T.]

CAMBRIDGE, MASS., May 7, 1901.

To Lick Observatory: (Received 11:40 A.M.)

Kiel cables that the bright comet discovered in the South will appear in the Northern Hemisphere. It was observed at the Cape of Good Hope on May 3.2115 G. M. T. in R. A. $3^h\ 40^m\ 32^s.4$; Decl. $-0^\circ\ 31'\ 49''$; and on May 4.2187 G. M. T. in R. A. $3^h\ 54^m\ 29^s.2$; Decl. $-0^\circ\ 18'\ 27''$. The comet is circular, less than 1′ in diameter, brighter than third magnitude, with well-defined nucleus, and tail longer than 2°.

(Signed) E. C. PICKERING.

CAMBRIDGE, MASS., May 10, 1901.

To Lick Observatory:

Kiel cables that elements and ephemeris of Comet *a* 1901 were computed by KREUTZ, from the observations of April 24, May 3, and May 4, as follows:

$$\begin{aligned} T &= \text{April } 24.22 \text{ G. M. T.} \\ \omega &= 202^\circ\ 50' \\ \Omega &= 109\ \ 57 \\ i &= 131\ \ 26 \\ \text{nat. } q &= 0.2446 \end{aligned} \left.\vphantom{\begin{aligned}\omega\\\Omega\\i\end{aligned}}\right\} \text{Ecliptic and mean Equinox for 1901.0.}$$

(Signed) E. C. PICKERING.

[The ephemeris is here omitted.]

LICK OBSERVATORY, Mt. Hamilton, Cal.,
May 15, 1901.
(Sent 10:15 P.M.)

To Harvard College Observatory,
Cambridge, Mass.:

The comet discovered at Queenstown was observed by AITKEN on May 15.6668 G. M. T. in R. A. $5^h\ 38^m\ 25^s.8$; Decl. $+3^\circ\ 52'\ 12''$.

(Signed) R. H. TUCKER, in charge.

CAMBRIDGE, MASS., May 8, 1901.

To Lick Observatory: (Received 12:50 P.M.)

The variation in the light of *Eros*, WENDELL, observer, is now zero.

(Signed) E. C. PICKERING.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

The appearance of the new star in the constellation *Perseus* aroused considerable interest in the astronomical world, such objects being rare in the history of astronomy. According to an article in *The Observatory* for March, there are only about a score on record, as the following list, taken from Miss CLERKE'S "System of the Stars" will show. The date of the discovery and the constellation in which they appeared are given:—

B. C. 134.	*Scorpio.*	827.	*Scorpio.*	1670.	*Vulpecula*
A. D. 123.	*Ophiuchus.*	1012.	*Aries.*	1848.	*Ophiuchus.*
173.	*Centaurus.*	1203.	*Scorpio.*	1860.	*Scorpio.*
386.	*Sagittarius.*	1230.	*Ophiuchus.*	1866.	*Corona.*
389.	*Aquila.*	1572.	*Cassiopeia.*	1876.	*Cygnus.*
393.	*Scorpio.*	1604.	*Ophiuchus.*	1885.	*Andromeda.*

To these must be added the *Novæ*, in *Auriga*, 1892, in *Norma*, 1893; in *Carina*, 1895; in *Centaurus*, 1895; in *Sagittarius*, 1898; and in *Aquila*, 1899; the four from 1893 to 1898 having been discovered photographically by the Harvard observers. The fact that the later years have witnessed the discovery of a greater number of such stars is but a natural result of the greater number of observers and the fact that in earlier times only the brighter *Novæ* were observed and recorded.

To find a parallel to the present case of *Nova Persei*, it is necessary to go back to the year 1604, when the star known as KEPLER'S, but discovered by BRUNOWSKI, appeared as bright as *Jupiter*. TYCHO'S star, in 1572, was first seen as bright as *Jupiter* and increased quickly, so that it became equal to *Venus;* the star in 1203 is said to have been equal to *Saturn*, and others in the list were equally conspicuous. The appearance of these was, in general, very sudden. It is of interest to note that all of these stars with the exception of the stars of 1012 and 1866 lay in or close to the Milky Way. The star of 1860 appeared suddenly as a 7th-magnitude star in the middle of a nebula or close cluster (Dreyer 6093), and the star in *Andromeda* was seen by Dr. HARTWIG on August 31, 1885, as a nucleus to the well-known nebula.

Sir WILLIAM HUGGINS pronounced the spectrum of *T Coronæ* to be due to glowing hydrogen, as though it were a sun like our own, with very exaggerated prominences. The star *Nova Cygni*, as seen by VOGEL, had at first a spectrum nearly continuous, crossed by bright lines due to hydrogen, and by others due to unknown substances, but finally became similar to the spectrum of a nebula.

The spectrum of the *Nova* in *Auriga* was crossed by bright lines due to hydrogen and other elements, but also by dark lines due to the same elements, the bright and dark lines being displaced relatively to each other. This was interpreted by Professor LOCKYER and others as an evidence of relative motion of two bodies; and from this it was assumed that two bodies had collided and that the outburst of heat was caused by the loss of kinetic energy. This is held by Professor LOCKYER to be true of *Nova Persei.* Another supposition of equal weight would be that the spectrum was that of a body of the solar type from which hydrogen gas was emanating with the velocity shown by the displacement of the lines, some 700 miles a second, which is not an inconceivable velocity. This latter supposition is, however, lacking in the fact that it does not assign a cause for the sudden outburst, as the collision theory does.

The article concludes with a statement of the present status of these variable stars. The star of KEPLER and the nucleus in the nebula of *Andromeda*, as well as *Nova Auriga*,* have disappeared, *T Coronæ* has resumed the condition it was in before 1866. *Nova Cygni* was seen as a 15th-magnitude star in 1885, and probably remains so at present. There is reason for thinking that *Nova Cygni* of 1670, which lasted as a bright star until 1672, was identical with the 11th-magnitude star found by Mr. HIND in 1852.

The variability of the light of the planet *Eros*, noted in the last issue of the *Publications*, has been investigated by M. ANDRÉ, of Lyons, who has determined its period and advanced an explanation for the variation. Combining his own results with those of Herr DEICHMUELLER at Bonn, M. ANDRÉ announced that the variation had a period of 5^h 16^m, and consisted of two waves. The second wave is shorter than the first by twenty-five minutes, although this is open to some question. Other observers had also noted the variation in light, but had fixed the period at $2^h\ 37^m.6$, or nearly one-half of the double period given by M. ANDRÉ.

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* See Professor CAMPBELL's note in Notices from Lick Observatory.

The light curve is almost precisely similar to those of *B Lyræ* and *U Pegasi*, the variation of light being continuous without any flat portion to the curve, as in stars of the *Algol* type. The variation is at least a magnitude, some observers making it as much as 1.5 or 2 magnitudes.

M. ANDRÉ offers as an explanation of the variation the supposition that the planet is double, the two minima being caused by the occultation of one of the pair by the other. He gives the elements of the system, the semi-major axis of relative orbit being but slightly greater than the sum of radii. The dimensions of the two bodies are as 3 to 2, with a mean density of the system of 2.4.

At Toulouse, M. L. MONTANGERAUD allowed the planet to trail on the plate, and the maxima and minima could thus be located. The period obtained was $2^h\ 38^m$, which is exactly one-half of that given by M. ANDRÉ.

Mr. CROMMELIN, in commenting in *The Observatory* on the theory advanced by M. ANDRÉ, says: "It is scarcely necessary to say that this hypothesis is only given provisionally and as affording a possible explanation of the light curve. The idea of a double minor planet is an utterly unexpected one, and one that does not at first sight commend itself as at all probable. But if we once admit the initial fact that *Eros* in February was subject to variations of light considerably exceeding a magnitude,—a fact for which the evidence is certainly strong,—we seem almost driven to some such hypothesis as that of M. ANDRÉ."

A note in the *Monthly Notices* of the Royal Astronomical Society for February, 1901, summarizes the report of M. BOUQUET upon the visual observations of the ten expeditions sent out by the French Academy of Sciences to observe the transit of *Venus* in 1882. The results of M. BOUQUET appeared in *Comptes Rendus* in 1899. The ten different expeditions occupied stations in North and South America, separated by 85° of latitude, while the most eastern were distant but 3° of longitude from the most western. The best determination of the solar parallax was therefore to be determined by HALLEY'S method from observations of second and third contact. The final result, as arrived at by M. BOUQUET, was 8″.80 for the solar parallax.

In the same issue of the *Monthly Notices* a review is given of Volume VIII, Part 2, of the "Annals of the Royal Observatory Cape of Good Hope," in which Dr. DAVID GILL publishes the results of his observations of stellar parallax in the Southern Hemisphere made since 1887.

The resulting stellar parallaxes published in this volume are:—

Star.	Mag.	Parallax.	Prob. Error.
Sirius	— 1. 8	0″.370	± 0″.010
Canopus	— 1. 0	0 .000	± 0 .010
Rigel.........	0.35	0 .000	± 0 .010
Achernar	0. 5	0 .043	± 0 .015
β *Centauri*	0. 8	0 .046	± 0 .017
α *Crucis*	1. 0	0 .050	± 0 .019
Spica	1. 2	— 0 .019	± 0 .010
Formalhaut ...	1. 3	0 .130	± 0 .014
α *Scorpii*......	1. 3	0 .021	± 0 .012
β *Crucis*	1. 5	0 .000	± 0 .008
α *Gruis*	1. 9	0 .015	± 0 .007
β *Hydri*	2. 9	0 .134	± 0 .007
τ *Ceti*	3. 6	0 .310	± 0 .012
Lacaille 2957..	6. 0	0 .064	± 0 .024
P XIV 212 ...	A 6. 3 B 7. 9	0 .167	± 0 .008
Z. C. V. 243 ..	8. 5	0 .312	± 0 .016

A TEXT-BOOK OF ASTRONOMY. By GEORGE C. COMSTOCK, Director of the Washburn Observatory and Professor of Astronomy in the University of Wisconsin. D. Appleton and Company, New York. 391 pages. Cloth. $1.30.

Written in simple, clear, and concise language, illustrated by appropriate and well-constructed figures, made interesting by apt and homely comparisons and useful by numerous and well-chosen exercises, this book forms a welcome addition to the list of elementary text-books of astronomy. Professor COMSTOCK has written a new book, and has not merely rearranged the material of earlier ones. His purpose is clearly outlined in the first paragraph of the preface:—

> "The present work is not a compendium of astronomy or an outline of popular reading in that science. It has been prepared as a text-book, and the author has purposely omitted from it much matter interesting as well as important to a complete view of the science, and has endeavored

to concentrate attention upon those parts of the subject that possess special educational value. From this point of view matter which permits of experimental treatment with simple apparatus is of peculiar value and is given a prominence in the text beyond its just due in a well-balanced exposition of the elements of astronomy, while topics, such as the results of spectrum analysis, which depend upon elaborate apparatus, are in the experimental part of the work accorded much less space than their intrinsic importance would justify."

Inspection of the table of contents shows that the author has departed widely from the conventional methods of treating the elements of the subject, especially in the first six and the eighth chapters. The special features of the book are numerous questions scattered throughout the text, to teach the student to think and construct as well as to read and assimilate; and many exercises, in the nature of laboratory work, all to be performed with simple apparatus, easily constructed by the students themselves. In these exercises the students obtain practice in the three fundamental processes of all practical astronomy, the measurement of time, angle, and distance. Although the exercises are numerous, still the author has not exhausted the list, and might with profit have given more.

It would have been well, if possible, to so arrange the material that the exercises, which all fall in the first five chapters, would be more distributed. It is not necessary, of course, that the teacher present the material in just the order given; but the facts are that the large majority of teachers will present it in that way. The author has, apparently, purposely avoided all reference to the Nautical Almanac and American Ephemeris. The wisdom of this is open to question. While it is unnecessary and certainly unwise to introduce the Ephemeris at first, and thus make the student dependent upon it, still I think it equally unwise to totally exclude it. An explanation of the Ephemeris and a few exercises which demand its use should, I think, be included in the most elementary course in practical astronomy. Any school in which astronomy is taught can surely afford to buy one of these books each year, and any person capable of teaching the subject should be able to use the book intelligently.

Many bits of good advice are given in connection with the exercises. On page 3, for instance, in connection with a measurement to be made, we find, " but perfection can seldom be attained, and one of the first lessons to be learned in any science which deals with measurement is, that however careful we may be in our work, some minute error will cling to it, and our results can be only approximately true. This, however, should not be taken as an excuse for careless work, but rather as a stimulus to extra effort in order that the unavoidable errors may be made as small as possible.''

A point to be commended is the use of the metric system throughout the exercises. In the descriptive parts of the text, however, the author retains the English units. Perhaps it is best to break away gradually, but I believe no criticism would have been offered if the metric system had been used throughout.

The illustrations and figures of the book are well chosen, and the student should learn something from each. Very few, if any, have been inserted for pictorial effect. Among the figures which deserve special mention are numbers 16 and 17 from which the position of any of the five brighter planets may be determined for a number of years; number 23, which ingeniously illustrates the tide-raising forces; number 54, illustrating the Moon's rotation; number 121, illustrating the determination of the parallax of the fixed stars.

Of the many apt illustrations contained in the book, the following (page 121) is one of the best:—

> "Every such timepiece, whether it be of the nutmeg variety which sells for a dollar, or whether it be the standard clock of a great national observatory, is made up of the same essential parts, which fall naturally into four classes, which we may compare with the departments of a well-ordered factory: I. A time-keeping department, the pendulum or balance-spring, whose oscillations must all be of equal duration. II. A power department, the weights or mainspring, which, when wound, store up the power applied from outside and give it out piecemeal as required to keep the first department running. III. A publication department, the dial and hands, which give out the time furnished by department I. IV. A transportation department, the wheels which connect the other three and serve as a means of transmitting power and time from one to the other. The case of either clock or watch is merely the roof which shelters it and forms no department of its industry. Of these departments the first is by far the most important, and its good or bad performance makes or mars the credit of the clock."

On page 209, in speaking of the law of the Sun's rotation as "very peculiar and extraordinary,'' the author gives a new lease of life to a long-standing misconception. Is there anything peculiar or extraordinary in the fact that the particles of a gaseous body move differently under the forces of rotation than do the particles of a solid body? Would it not rather be peculiar and extraordinary if a gaseous body did rotate in the same way as a solid one? A few years ago Dr. WILCZYNSKI, in "Hydrodynamische Untersuchungen mit Anwendungen auf die Theorie der Sonnenrotation," showed that the law of the Sun's rotation was only one of an infinite number of ways in which a gaseous body might rotate.

The last chapter, "Growth and Decay," deserves special mention. It is a conservative philosophic exposition of the best theories of solar and sidereal evolution, and although not out of place in a high-school text, it might well form a part of a larger treatise.

The work of the publishers has been most excellently done, and the book, as a whole is, I think, the best elementary astronomy yet published. S. D. T.

The Directors of the Benjamin Apthorp Gould Fund announce that the following grants have been made: To Mr. JOHN A. PARKHURST, $30; to Dr. HERMAN S. DAVIS, $500; to Mr. PAUL S. YENDELL, $225; to Professor SIMON NEWCOMB, $25. A considerable additional amount of income has accrued, for the distribution of which applications are awaited. In addition to the above call for applications the Directors, desiring to stimulate the participation of American astronomers in the attempt to bring up the arrears of cometary research, offer to them the sum of $500 for computation of the definitive orbits of comets (see list in *A. J.*, 493, p. 104); this sum to be distributed at the average rate of $100 for each computation,—the amount to vary according to the relative difficulty of the computation, and to be determined by the Directors of the Gould Fund. Computers should promptly notify the Directors (Professors LEWIS BOSS and ASAPH HALL and Dr. S. C. CHANDLER) of their participation or desire to participate, and manuscripts should be submitted not much later than July 1, 1902.

The degree of Doctor of Philosophy was recently conferred by the University of California upon two students of astronomy. Mr. R. T. CRAWFORD, for three years Fellow at the Lick Observatory, presented Astronomy as his major subject, and Mathematics and Physics as his minors. His thesis was entitled, "Determination of the Constant of Refraction from Observations made with the Repsold Meridian-Circle of the Lick Observatory." Mr. F. E. Ross, Fellow at the Lick Observatory in 1898–'99, presented Mathematics as his major, and Astronomy and Physics as his minors. His thesis was "On Differential Equations belonging to a Ternary Linearoid Group."

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The meeting of the Board of Directors of the Astronomical Society of the Pacific, and the meeting of the Society itself, which were to be held at the Lick Observatory on June 8th, were adjourned, without transacting business, for lack of a quorum.

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Mr. S. D. TOWNLEY	*First Vice-President*
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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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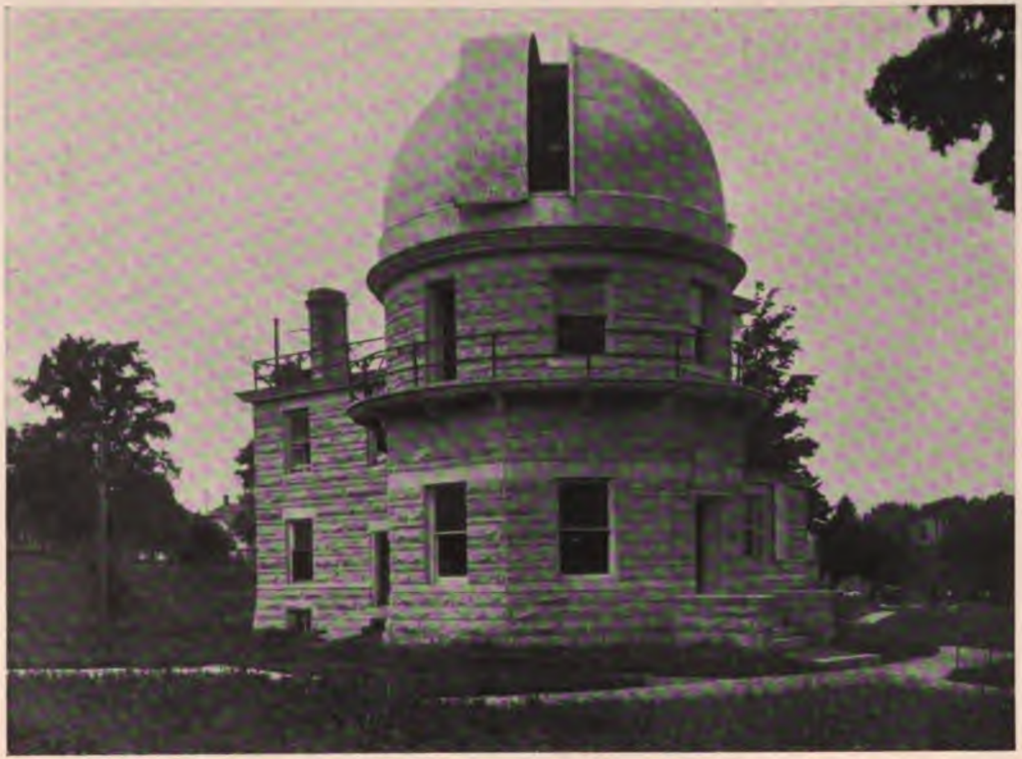

KIRKWOOD OBSERVATORY, INDIANA UNIVERSITY

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THE KIRKWOOD OBSERVATORY OF INDIANA UNIVERSITY.

BY JOHN A. MILLER, DIRECTOR.

At its November meeting of 1899, the board of trustees of Indiana University appropriated a sum of money for the purchase of a telescope and some accessories, and for the erection of an observatory. The design of the board, that this equipment is to be used in part for instruction and in part for purposes of research, determined largely the character of the instruments afterwards purchased.

The observatory, a cut of which appears on the opposite page, is built of Indiana limestone, in which this region abounds, and was completed last winter. It contains six rooms — a library and computing-room; a lecture-room, which may be darkened at any time, equipped with a Colt electric lantern, lantern-slides, and other illustrative apparatus; a convenient dark-room; a transit-room; the dome-room, and a room similar to it and immediately below it.

The skeleton of the dome, which is twenty-six feet in diameter, is of white pine, and is built according to plans furnished by Messrs. WARNER & SWASEY, who also furnished the running mechanism. It is covered with tin. The performance of both dome and shutter is entirely satisfactory. In the dome-room is mounted a twelve-inch refractor. The objective is by BRASHEAR, and is of high optical excellence, giving star-images which are free from fringes or distortion and on a black field. The mounting is by WARNER & SWASEY. It is provided with coarse and fine circles in both Declination and Right Ascension, the fine ones being provided with reading-microscopes and electric illumination. The star-dial, from which the Right Ascensions can be read directly, is of almost indispensable convenience. The driving-clock drives regularly, and the entire mounting is of the highest mechanical excellence. The telescope has as accessories a micrometer, by WARNER & SWASEY, provided with electric illumination; a polarizing helioscope, and a battery of positive and negative eye-pieces. The transit-room contains a small universal instrument by BAMBERG, a chronograph by FAUTH & COMPANY, a Bond sidereal chronometer, and a sidereal clock.

These instruments, together with a portrait lens of five inches aperture and a Browning equatorial of four inches aperture, which for many years have been the property of the university, constitute a nucleus around which the university authorities hope to collect a more complete equipment.

The observatory bears the name of Dr. DANIEL KIRKWOOD, the eminent astronomer, who for nearly half a century was a member of the faculty of the university, and who by his manly qualities won the lasting esteem of his students and colleagues, and by his devotion to his science a lasting name among his contemporaries.

The observatory was formally dedicated on May 15, 1901. The dedicatory address was given by Professor W. J. HUSSEY, Astronomer in the Lick Observatory. He spoke of "Astronomy and Modern Life." President JOSEPH SWAIN spoke of "Personal Recollections of Dr. KIRKWOOD."

We of the observatory take this opportunity to acknowledge our obligations to Professor HUSSEY for his thoughtful address and his kindly interest in our equipment.

DANIEL KIRKWOOD.*

BY JOSEPH SWAIN.

At Riverside in California there died in his eighty-first year an aged man who was of more interest to the people who have known him and loved him (for to have known him was to love him) than all the groves of orange and palm-trees, than all the snow-capped mountains, the Italian skies, the unequaled climate, or magnificent landscapes of that favored land. It is of this venerable man I wish to speak to you on this occasion.

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* An address delivered at the dedication of the Kirkwood Observatory, University of Indiana, May 15, 1901.

The city of Riverside covers several square miles of territory and has hundreds of orange-groves and vineyards within its corporate limits. In one of these groves, seven acres in extent, lived DANIEL KIRKWOOD, the subject of this sketch.

While Professor KIRKWOOD passed his declining years in the picturesque surroundings of Southern California, it is not there that he made his name and lived the best part of his life. His twenty-seven years of active service in the interest of manhood, science, and higher education in general in Indiana are the brightest and best years of his life.

The esteem in which Dr. KIRKWOOD was held in Bloomington is indicated by the fact that the street leading to the university bears his name, and that every old citizen points out with evident pride the house in which he lived on the corner of College Avenue and Tenth Street. Indiana University has appropriately expressed its appreciation by naming one of the halls in his honor and also the new astronomical observatory.

DANIEL KIRKWOOD was of Scotch-Irish descent, his grandfather coming from Ireland in 1771, and settling in Delaware. His parents, JOHN and AGNES (HOPE) KIRKWOOD, were both born in this country. Professor KIRKWOOD was born in Hartford County, Maryland, September 27, 1814. His early life was spent on the farm, his first attendance at school being in his native county. Having little taste for farming, he entered the York County Academy, at York, Pennsylvania, in 1834. He had taught a country school at Hopewell, York County, the previous year. A pupil in this school wishing to study algebra, asked young KIRKWOOD to instruct him. A copy of BONNYCASTLE'S algebra was secured, and the two studied together, Mr. KIRKWOOD leading the way. Professor BRUNNOW, at one time professor of astronomy at Ann Arbor, once had a class of one in mathematical astronomy consisting of the afterward famous Professor WATSON. Professor BRUNNOW said he had never had so fine a class as this one either before or since. It is safe to say that no class of one ever had a more inspiring teacher of algebra than this young man in 1833 at Hopewell in Pennsylvania, for the young KIRKWOOD must have come to his first lessons in algebra with all the enthusiasm of youth and the ardor of "love at first sight." He was elected first assistant and mathematical instructor in York County Academy in 1838. While here he trained many students in mathematics, one of whom, SAMUEL R. FRANKLIN, afterward became superintendent of the Observatory at Washington. Professor KIRKWOOD resigned his position in 1843 to accept the principalship of the Lancaster High School, Pennsylvania, and a few years later he became principal of the Pottsville Academy. In 1845 he was married to Miss SARAH A. MCNAIR, of Newton, Bucks County, Pennsylvania. He was professor of mathematics in Delaware College from 1851 to 1856. the last two years being its president. In speaking to me one day about this period of his presidency, he said, "Concerning that, the less said the better." He evidently did not enjoy the responsibility of the president's position. He was a student and teacher, and set a noble example which cannot be overestimated, but he did not like to assume or use authority. He was always the embodiment of loyalty to the institution he served, but begged to be excused from anything which brought him into public notice. He shrank intuitively from public gaze or appreciation. This was so strong that he could hardly be induced to give a public lecture, and never an impromptu address. I remember at one time there was a public gathering in the College Chapel at Bloomington. Some impromtu speeches had been made, and Dr. KIRKWOOD, being immensely popular with the students, was called upon by them to make a speech. The President of the University, who was presiding, stepped to him and asked him if he would not respond. He begged to be excused, and asked the President to say that as he had often excused the students from recitations in the classroom, he trusted they would now excuse him. This created a laugh at the expense of the students, and they did not call on him again that day.

He was a member of the Presbyterian Church, and was always a faithful attendant at its services. He was a teacher in the Sunday-school. For many years he taught a class of boys from twelve to fourteen years of age. I remember once he told me, with evident gratification, that these boys decided that they would not have any other teacher when he went away. He was a great reader of the Bible, preferring to read it in the Greek. In NORTHROP'S book, "A Cloud of Witnesses," there is a letter from Dr. KIRKWOOD which explains itself. It is as follows :—

> "I am asked to give my opinion of Christ and the Bible. Let me say in answer to the old question, 'What think ye of Christ?' that his

name is above every name. I regard him as the Divine Saviour of men. I accept him as my Saviour, and place all my hope of Salvation in him. I accept the Scriptures as a revelation of what man is to believe concerning God, and what duty God requires of man."

Professor KIRKWOOD deplored the fact that there has been a tendency to skepticism among some scientific men. He says:

> "It will be noted, however, by careful observers that this tendency is more distinctly marked among specialists, men whose minds have been biased by continued and almost exclusive devotion to physical research, while the claims of Christianity and the evidence of its truth have been persistently ignored. But our own time is no exception to the historic fact that in all ages minds of the broadest culture have accepted Christianity."

He thought there is no necessary antagonism between physical science and Christianity, and the study of physical science was not of necessity prejudicial in the student himself to a personal acceptance of Christianity. Dr. KIRKWOOD had a profound belief in God and his controlling influence over the affairs of men. I remember being present at a certain organization when resolutions of sympathy were being passed on account of the death of a certain young man. Dr. KIRKWOOD had written the resolutions and had read them to the meeting. A member of the meeting objected to the form of his expressions as hackneyed and the sentiment as not being in accordance with the belief of all men. Dr. KIRKWOOD said with courtesy but decision and the emphasis of deep conviction, "I believe just that." He said no more, but the resolution was adopted as read.

I quote the following from an article by Professor ALEY:—

> "His study of the stars has strengthened his belief in God. To his mind, with its faith strengthened by a firm grasp of the mightiest works of God, unbelief is impossible, and he can hardly understand how honest unbelief can exist in another. Some years ago he gave a beautiful demonstration before a class. A student asked: 'Is that always true?' 'Yes,' said he, 'as true as that there is a God in heaven.' 'But,' said the student, 'what would you say to him who does not believe in God?' Straightening up to his full height, and with glittering eye he said, 'I would try to keep my temper and get away as quickly as possible.' The writer well remembers his first visit to Bloomington. He went into a barber-shop, and, as it was a rainy day, there was quite a crowd of loafers, white and black, professional men and day laborers. By chance the conversation changed to men. Every man present found his ideal in DANIEL KIRKWOOD. No man ever received a higher tribute of praise. His life was so simple, so pure, and so true that the student, the philosopher, and the common man can all find in him the ideal."

A friend of mine once lived for a time in Dr. KIRKWOOD'S house. One evening something attracted his attention in the next room. He listened and found Dr. KIRKWOOD was reading the Scriptures aloud to his wife. The reading was followed by a solemn prayer. My friend thought to himself: "Here is a genuine Christian. He is following the teaching of Christ — 'But thou when thou prayest, enter into thy closet, and when thou hast shut thy door, pray to thy Father which is in secret, and thy Father which seeth in secret shall reward thee openly.'"

The domestic life of Dr. KIRKWOOD was very beautiful. He was at his best at home. His fireside was as attractive to him as his study. His wife was a quiet, domestic woman, who found her chief enjoyment in her home and with her friends. She was only interested in the scientific work of her husband as a loving and dutiful wife who was interested in everything connected with him. She was the devoted helper of a truly great man. When visitors happened in, she always wanted him to talk to them and entertain them. She felt that she had done her part if she encouraged him to talk. On such an occasion it was a genuine pleasure to see the enjoyment she derived from his conversation.

Professor KIRKWOOD was first introduced to the scientific world by the publication, in 1849, of his analogy between the periods of the rotations of the primary planets. The statement of the law is as follows: The square of the number of rotations made by a planet during one revolution around the Sun is proportional to the cube of the diameter of its sphere of attraction. PROCTOR, the eminent English astronomer, gave KIRKWOOD the name of "the KEPLER of America," after the announcement of KIRKWOOD'S Law. This was fitting, as the form of the law is similar to KEPLER'S Third Law: The square of the number of the revolutions of a planet is proportional to the cube of its mean distance from the Sun. Indeed, the form of the Law of KEPLER first suggested to Dr. KIRKWOOD the form of this law. This law has always been regarded by mathematicians as a confirmation of the Nebular Hypothesis. The law is an empirical one, and has never been demonstrated by rigid mathematical analysis. It is now in the same stage of KEPLER'S Third Law before it was shown to be the direct result of the Law of Gravity. The mathematician who is able to give it a rigid mathematical demonstration is sure of remembrance by a grateful posterity.

When about fifty asteroids were known in the solar system, Professor KIRKWOOD conceived the notion that in those spaces where simple commensurability with *Jupiter* occurs, there must be gaps in the asteroid zone. It was then, however, only a theory, as the number of asteroids sufficient for its verification were not known. Yet on its first announcement it met with favor, and Mr. PROCTOR, the eminent astronomer, accepting Professor KIRKWOOD'S notion, wrote in 1870: "We may assume that when many more asteroids have been discovered, that the law will appear more distinctly." The number of asteroids known were then sufficient only to indicate the law; now the number discovered and orbits computed have reached 450. Professor KIRKWOOD has shown that these gaps actually exist and assigned a physical cause for them. He originally published his discoveries concerning these chasms in the Proceedings of the American Association for the Advancement of Science in 1866. Circumstances, however, which need not here be stated, induced Professor KIRKWOOD to give a résumé of his discussions in the Proceedings of the American Philosophical Society for 1883. From this paper the following is taken :—

> "In those parts of the zone of minor planets where a simple relation of commensurability would obtain between the period of an asteroid and that of *Jupiter*, the original planetary matter was liable to great perturbations. The result of such disturbance by the powerful mass of *Jupiter* was the necessary formation of gaps in the asteroid zone."

Professor KIRKWOOD was the first to show that the divisions of *Saturn's* rings are due to the same cause as the gaps in the zone of asteroids. The treatise of Dr. MEYER, of Geneva, on *Saturn's* rings published in 1883, and leading to the same or a similar result, is a gratifying confirmation of Professor KIRKWOOD'S discovery.

He has contributed nearly two hundred articles to various scientific and popular journals. He is the author of a well-known book on comets and meteors, as well as an earlier book on meteoric astronomy. He is also the author of a little book on the asteroids. He was at one time mathematical editor of the *Indiana School Journal*. He also contributed popular articles for several years to the *Indianapolis Journal*. The astronomical articles in *Appleton's Annual Encyclopædia* were written for several years by him. *The Popular Science Monthly*, *The Analyst*, *American Journal of Science*, *The Sidereal Messenger*, *Nature*, and other journals, were always glad to get articles from his pen. Dr. KIRKWOOD's writings are all characterized by simplicity, brevity, and purity. Such ability as he had to say clearly and forcibly what he had to say is possessed by few.

In September of 1889 he asked me to come to his study in the afternoon. I went and found that he wanted to see me about some books. He thought that the greater part of his library would no longer be useful to him, and that it should be placed where it would be of most service. He wanted to give some books to the college library, and he wanted me to select some that the university should buy. We found among his books several unpublished manuscripts. Professor GREEN and I suggested to him that the library would be glad to get these manuscripts, but he refused. They were manuscripts that he concluded, after mature consideration, he would not publish, and he feared their future publication if given to the library, so he consigned them to the fire, much to our disappointment. Dr. KIRKWOOD once having a clear notion of what he wished to do, was very slow to alter his determination. He made up his mind slowly and after very critical examination of the subject in hand, but relied upon his conclusion when reached. Once I suggested to him that he should have all his writings, scattered in numerous magazines, collected together and edited during his lifetime, so that it would be known just what he had done, and his articles would then be much handier for reference. His reply was this : "Anything that deserves to live will, and that which does not deserve it ought to die." He was not troubling himself about his future fame. His theory was that if he had not done anything worthy of future reference he wanted to be forgotten. He was not troubled by any thirst for a false and fictitious glory.

Dr. KIRKWOOD's position among scientific men and non-scientific men was unusual. He had the respect and confidence of both alike. The most selfish man seemed to lose his selfishness in his presence. Every one seemed to instinctively feel that he was a great man, and a criticism upon him would be only acknowledging one's own lack of appreciation. While it is as a genial and good man that most of the people who have come into personal contact with Professor KIRKWOOD have known him, it is as a scientist that he is best known to the people of the United States and of Europe. He is probably better known in Great Britain than he is in America. He seemed to have through his writings the warm friendship of astronomers everywhere, even though they had not met him. Several years ago, when PROCTOR, the eminent English astronomer, was in this country, this incident occurred: PROCTOR lectured in Indianapolis. After the lecture a professor from a sister institution approached him and invited him to his town to lecture the next night. PROCTOR said: "No; I came to America to see Dr. KIRKWOOD. To-morrow is my opportunity, and I am going to Bloomington to see him."

Eighteen years ago, when I was an assistant of Dr. KIRKWOOD, I wrote and published this paragraph:—

> "'When I die, I want to go where Dr. KIRKWOOD goes,' was the simple eulogy of one of his admirers. Whatever may be said of this sentiment, certain it is that during fifty years as a teacher, he has gained from his students such universal love and admiration as few men can enjoy, and while as a mathematician he has made many valuable contributions to science, as a genial, temperate, and genuine man, he has solved the problem of gracefully growing old."

In intellect he was keen, logical, and far-seeing. In integrity he was without reproach. He was "spotless before the world." In private character he was pure as an infant. He was in sympathy with humanity. He was as natural as a child and as free from self-conceit as the "lilies of the field." He saw and spoke the truth. The laws of Nature were to him the laws of God. The heavens indeed declared His glory. In revealing the secrets of the stars he revealed the beauty of his life. KIRKWOOD the scientist we admire, but KIRKWOOD the man we love. These characteristics made DANIEL KIRKWOOD one of the greatest of Indiana's roll of heroes and one of the most lovable of men of any country or age.

PLANETARY PHENOMENA FOR SEPTEMBER, OCTOBER, NOVEMBER, AND DECEMBER, 1901.

By MALCOLM MCNEILL.

SEPTEMBER.

The Sun crosses the celestial equator and autumn begins September 23d, 10 A.M. Pacific time.

Mercury is an evening star throughout the month, having passed superior conjunction on August 27th. At the close of the month it is well out toward east elongation, but the great southern declination of the planet makes the interval between sunset and the setting of the planet too short for naked-eye visibility of the planet.

Venus is an evening star. It increases its distance from the Sun from 32° to 37°, and it remains above the horizon a few minutes longer after sunset than during August. At the end of September the interval is about an hour and a half. It moves 33° east and 14° south through *Virgo* into *Libra*. On September 8th it passes about 3° north of the first-magnitude star *Spica*.

Mars is much nearer the Sun and sets earlier than during August. Its distance from us increases about twelve millions of miles, and it is about twice as far from us as we are from the Sun. Its apparent motion among the stars is 20° east and 7° south from *Virgo* into *Libra*, and at the end of the month it is about 4° east of *Venus*, which is rapidly overtaking it.

Jupiter and *Saturn* remain in *Sagittarius*, and are quite conspicuous in the southwestern sky in the evenings. *Jupiter* has ceased his retrograde motion and is again moving eastward, but not rapidly as yet, making about 1° 41′ during the month. *Saturn* keeps up his westward motion until September 14th, and then begins to move eastward, but the whole motion is only about 15′, and, as far as naked-eye observations show, the planet is practically stationary among the stars. *Jupiter* and *Saturn* approach each other a little more than 1°, and on September 30th they are not quite 6° apart.

Uranus is about two hours' motion ahead of *Jupiter* and *Saturn*, and its distance from the Sun is getting to be too small for convenient evening observations. It remains above the horizon until nearly 9 P.M. on September 30th; but its small size makes observation difficult unless the planet is at a good altitude.

Neptune is an early morning object.

OCTOBER.

There will be a partial eclipse of the Moon, on October 27th, not visible in any part of the western hemisphere except Alaska, but visible generally throughout the eastern hemisphere, except in western Europe. At the maximum only about one quarter of the Moon's diameter will be covered.

Mercury is an evening star, and comes to greatest east elongation on the morning of October 12th; but its very great southern declination (12° south of the Sun) makes the interval between the setting of the Sun and planet less than one hour, and although the elongation (25°) is comparatively large, being only a fortnight from aphelion, the planet will scarcely be visible to the naked eye.

Venus is increasing its apparent distance from the Sun, and by the close of the month the elongation will be more than 40°. The interval from sunset to the setting of the planet increases, and is well over two hours by the end of the month. The planet moves about 35° eastward and 8° southward among the stars from *Libra* through *Scorpio* and into *Ophiuchus.* On the morning of October 9th it overtakes and passes *Mars*, also moving in the same general direction but more slowly. At the time of nearest approach *Venus* is a little less than 1° south of *Mars. Venus* also is in conjunction with *Uranus* on the morning of October 25th, the former being 2° 21′ south.

Mars is still in the southwestern sky in the early evening, but sets less than two hours after sunset, and has become so faint as to be no longer conspicuous. It is nearly at its maximum distance from us, but will not reach it for several months. It moves about 21° east and 5° south from *Libra* through *Scorpio.*

Jupiter and *Saturn* still keep their position in *Sagittarius*, and by the close of the month remain above the horizon less than four hours after sunset. Both are moving eastward among the stars, *Jupiter* 4° and *Saturn* a little more than 1° during the month, and by the end they are less than 3° apart.

Uranus is nearer the Sun than during September, and by the end of the month sets about two hours after sunset. It is rather too low down to be seen with the naked eye.

Neptune is rising earlier, and is well up during the late evening.

NOVEMBER.

There will be an annular eclipse of the Sun on November 10th, not visible in the western hemisphere. The central line runs from the Mediterranean Sea through Egypt, Arabia, the Indian Ocean, just touching southern Hindustan and Siam, and ending in the Philippines.

Mercury passes inferior conjunction with the Sun and becomes a morning star on November 4th. It rapidly recedes from the Sun, and after November 11th it rises more than an hour before sunrise. It reaches greatest west elongation on November 20th, and then rises more than an hour and a half before sunrise. This is the best opportunity of the year for seeing *Mercury* as a morning star.

All of the other planets, except *Neptune*, are in the southwestern sky in the early evening. but some of them are too near the Sun for easy observation. *Venus* reaches nearly its maximum distance from the Sun, and by the close of the month sets more than three hours after sunset. It moves about 33° westward and 2° northward from *Ophiuchus* through *Sagittarius* into *Capricorn*, passes *Jupiter* on November 17th, and *Saturn* on November 18th. For several days the three planets are near each other, *Venus* being about 3° south of the other two. This close conjunction of three bright planets is a very unusual occurrence.

Mars is down below *Venus*, and toward the close of the month will not be a very easy object, but can still be made out in good weather conditions. It moves eastward about 22° from *Scorpio* through *Ophiuchus* into *Sagittarius*. It passes *Uranus* less than 1° south on the night of November 3–4th, and at the close of the month is about 10° from *Jupiter* and *Saturn*.

Jupiter and *Saturn* are still high enough to be seen in the early evening. Both are moving rapidly eastward from the constellation *Sagittarius* toward *Capricorn*. They come to conjunction on the evening of November 27th, *Jupiter* then being 0° 27′ south of *Saturn*, a distance rather less than the Moon's diameter. At the beginning of the month *Jupiter* was about 3° west of *Saturn*.

Uranus is drawing closer to the Sun and by the end of the month sets only a half an hour after sunset.

DECEMBER.

The Sun passes the solstice and winter begins December 22d, 4 A.M., P. S. T.

The Earth is in perihelion December 31st, 10 P.M., P. S. T.

Mercury is a morning star at the beginning of the month, rising about an hour and a half before sunrise, but is approaching the Sun. The interval between the rising of the planet and the Sun is, however, more than an hour until after December 10th. After that it is too near the Sun to be seen, and by the end of the month it has nearly reached superior conjunction. It is in conjunction with *Uranus* on the morning of December 18th.

Venus reaches its greatest east elongation on December 4th. It is then 47° 19′ from the Sun, and by the end of the month the distance will have diminished about 4°. Owing to the relative motions of the Sun and planet in declination, however, the interval between sunset and the setting of the planet will go on increasing throughout the month, being more than three hours and a halt toward the close. *Venus* has been gradually increasing in brightness as it moved out toward greatest elongation, and will still farther increase until about half-way between that point and inferior conjunction. The maximum will occur during January, 1902.

Mars is gradually being overtaken by the Sun in their common eastward motion, but will not set until about an hour and a half after sunset throughout the month. It is growing so faint that weather conditions must be very good in order to see it. It passes 1° 19′ south of *Saturn* on the morning of December 14th, and 0° 52′ south of *Jupiter* on the morning of December 17th. For several days the three planets are very close together.

Jupiter and *Saturn* are drawing close to the Sun, and by the close of the month both set less than an hour after sunset. It will be hardly possible to see *Saturn* for the last week or so, but *Jupiter*, on account of its greater brightness, may remain visible throughout the month. Both planets are still moving eastward among the stars, but the greater motion of *Jupiter* causes them to separate, and on December 31st *Jupiter* will be about 4° east of *Saturn*.

Uranus is too near the Sun to be seen and passes conjunction on the afternoon of December 9th.

Neptune is in opposition with the Sun on December 24th.

SEPTEMBER–OCTOBER, 1901.

PHASES OF THE MOON, P. S. T.

Last Quarter . . .	Sept. 5,	5^h	27^m	A. M.
New Moon . . .	Sept. 12,	1	18	P. M.
First Quarter . . .	Sept. 20,	5	33	
Full Moon . . .	Sept. 27,	9	36	
Last Quarter . . .	Oct. 4,	12	52	
New Moon . . .	Oct. 12,	5	11	A. M.
First Quarter . . .	Oct. 20,	9	58	
Full Moon . . .	Oct. 27,	7	6	

THE SUN.

1901.		R. A.	Declination.	Rises.	Transits.	Sets.
Sept.	1,	$10^h 40^m$	$+ 8° 27'$	$5^h 31^m$ A.M.	noon	$6^h 29^m$ P.M.
	11,	11 16	+ 4 44	5 41	$11^h 57^m$ A.M.	6 13
	21,	11 52	+ 0 53	5 50	11 53	5 56
Oct.	1,	12 28	− 3 1	6 0	11 50	5 40
	11,	13 4	− 6 52	6 11	11 47	5 23
	21,	13 42	− 10 33	6 21	11 45	5 9
	31,	14 20	− 13 59	6 32	11 44	4 56

MERCURY.

Sept.	1,	10 59	+ 8 14	5 51 A.M.	12 19 P.M.	6 47 P.M.
	11,	12 2	+ 0 26	6 42	12 43	6 44
	21,	12 59	− 6 55	7 24	1 0	6 36
Oct.	1,	13 51	− 13 18	7 59	1 13	6 27
	11,	14 36	− 18 13	8 22	1 18	6 14
	21,	15 6	− 20 44	8 23	1 9	5 55
	31,	14 55	− 18 29	7 24	12 19	5 14

VENUS.

Sept.	1,	12 41	− 3 48	8 13 A.M.	2 1 P.M.	7 49 P.M.
	11,	13 25	− 8 52	8 36	2 5	7 34
	21,	14 9	− 13 38	8 58	2 11	7 24
Oct.	1,	14 56	− 17 54	9 20	2 17	7 14
	11,	15 43	− 21 28	9 43	2 26	7 9
	21,	16 33	− 24 9	10 4	2 36	7 8
	31,	17 23	− 25 47	10 23	2 47	7 11

MARS.

Sept.	1,	13 53	− 11 58	9 54 A.M.	3 13 P.M.	8 32 P.M.
	11,	14 18	− 14 19	9 48	2 59	8 10
	21,	14 45	− 16 33	9 44	2 46	7 48
Oct.	1,	15 13	− 18 36	9 39	2 34	7 29
	11,	15 42	− 20 25	9 36	2 24	7 11
	21,	16 12	− 21 58	9 34	2 15	6 56
	31,	16 43	− 23 11	9 30	2 6	6 42

JUPITER.

Sept.	1,	18 14	− 23 31	2 59 P.M.	7 33 P.M.	12 7 A.M.
Oct.	1,	18 21	− 23 31	1 8	5 42	10 16 P.M.
Nov.	1,	18 39	− 23 21	11 23 A.M.	3 58	8 33

SATURN.

Sept. 1,	18 43	—22 43	3 23 P.M.	8 2 P.M.	12 41 A.M.
Oct. 1,	18 44	—22 46	1 25	6 4	10 43 P.M.
Nov. 1,	18 50	—22 41	11 30 A.M.	4 9	8 48

URANUS.

Sept. 1,	16 46	—22 23	1 26 P.M.	6 5 P.M.	10 44 P.M.
Oct. 1,	16 49	—22 28	11 31 A.M.	4 10	8 49
Nov. 1,	16 54	—22 38	9 36	2 14	6 52

NEPTUNE.

Sept. 1,	6 5	+22 17	12 6 A.M.	7 26 A.M.	2 46 P.M.
Oct. 1,	6 6	+22 16	10 9 P.M.	5 29	12 49
Nov. 1,	6 6	+22 15	8 6	3 26	10 46 A.M.

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

III, R,	Sept. 2,	4^h 39^m P. M.	I, R,	Oct. 1,	2^h 33^m P. M.
II, R,	4,	8 46	II, R,	6,	8 38
I, R,	6,	7 50	I, R,	8,	4 28
III, D,	9,	5 35	III, R,	15,	4 45
III, R,	9,	8 40	I, R,	15,	6 23
IV, D,	11,	10 39	III, D,	22,	5 35
II, R,	11,	11 24	III, R,	22,	8 45
I, R,	13,	9 45	I, R,	24,	2 47
I, R,	15,	4 14	II, R,	24,	3 13
III, D,	16,	9 35	I, R,	31,	4 42
II, R,	22,	3 22	II, R,	31,	5 52
I, R,	22,	6 9			
IV, D,	28,	4 40			
IV, R,	28,	7 47			
II, R,	29,	6 0			
I, R,	29,	8 4			

NOVEMBER–DECEMBER, 1901.

PHASES OF THE MOON, P. S. T.

Last Quarter, . . .	Nov. 2,	11^h 24^m P. M.
New Moon, . . .	Nov. 10,	11 34
First Quarter, . . .	Nov. 19,	12 23 A. M.
Full Moon, . . .	Nov. 25,	5 18 P. M.
Last Quarter, . . .	Dec. 2,	1 50
New Moon, . . .	Dec. 10,	6 53
First Quarter, . . .	Dec. 18,	12 35
Full Moon, . . .	Dec. 25,	4 16 A. M.

THE SUN.

1901.	R. A.	Declination.	Rises.	Transits.	Sets.
Nov. 1,	14^h 24^m	— $14°$ $18'$	6^h 33^m A.M.	11^h 44^m A.M.	4^h 55^m P.M.
11,	15 4	— 17 19	6 44	11 44	4 44
21,	15 45	— 19 50	6 57	11 46	4 35
Dec. 1,	16 28	— 21 45	7 7	11 49	4 31
11,	17 11	— 22 59	7 16	11 53	4 30
21,	17 55	— 23 27	7 23	11 58	4 33
31,	18 40	— 23 8	7 27	12 3 P.M.	4 39

MERCURY.

Nov. 1,	14 51	— 17 53	7 14 A.M.	12 11 P.M.	5 8 P.M.
11,	14 13	— 11 35	5 32	10 53 A.M.	4 14
21,	14 29	— 12 14	5 12	10 30	3 48
Dec. 1,	15 19	— 16 47	5 39	10 41	3 43
11,	16 20	— 21 10	6 16	11 2	3 48
21,	17 26	— 24 3	6 57	11 29	4 1
31,	18 36	— 24 53	7 32	noon	4 28

VENUS.

Nov. 1,	17 28	— 25 54	10 25 A.M.	2 48 P.M.	7 11 P.M.
11,	18 18	— 26 17	10 37	2 59	7 21
21,	19 7	— 25 31	10 43	3 8	7 33
Dec. 1,	19 54	— 23 43	10 41	3 15	7 49
11,	20 36	— 21 4	10 32	3 17	8 2
21,	21 12	— 17 46	10 17	3 15	8 13
31,	21 43	— 14 9	9 53	3 5	8 17

MARS.

Nov. 1,	16 46	— 23 17	9 29 A.M.	2 5 P.M.	6 41 P.M.
11,	17 18	— 24 5	9 26	1 58	6 30
21,	17 51	— 24 28	9 22	1 52	6 22
Dec. 1,	18 24	— 24 24	9 16	1 46	6 16
11,	18 58	— 23 53	9 8	1 40	6 12
21,	19 32	— 22 55	8 57	1 34	6 11
31,	20 5	— 21 30	8 45	1 28	6 11

JUPITER.

Nov. 1,	18 39	— 23 21	11 23 A.M.	3 58 P.M.	8 33 P.M.
Dec. 1,	19 3	— 22 53	9 47	2 24	7 1
Jan. 1,	19 33	— 22 0	8 11	12 52	5 33

SATURN.

Nov.	1,	18 50	—22 41	11 30 A.M.	4 9 P.M.	8 48 P.M.
Dec.	1,	19 2	—22 28	9 44	2 23	7 2
Jan.	1,	19 17	—22 6	7 55	12 36	5 17

URANUS.

Nov.	1,	16 54	—22 38	9 35 A.M.	2 14 P.M.	6 53 P.M.
Dec.	1,	17 2	—22 49	7 45	12 23	5 1
Jan.	1,	17 10	—23 0	5 52	10 29 A.M.	3 6

NEPTUNE.

Nov.	1,	6 6	+22 15	8 6 P.M.	3 26 A.M.	10 46 A.M.
Dec.	1,	6 3	+22 15	6 6	1 26	8 46
Jan.	1,	5 59	+22 15	3 57	11 17 P.M.	6 37

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

I, R, Nov.	7,	6^h 37^m P. M.	II, R, Dec.	1,	5^h 43^m P.M.
I, R,	16,	3 0	IV, D,	4,	4 51
I, R,	23,	4 55	I, R,	9,	3 13
II, R,	25,	3 6	I, R,	16,	5 8
III, R,	27,	4 50			
I, R,	30,	6 50			

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

CAPELLA AGAIN.

Since the discovery that *Capella* is a spectroscopic binary it has been of much interest to see if it is also a telescopic double star. I have given the result of my examination of it for 1900, having this object in view, in No. 484 of the *Astronomical Journal* and in No. 75 of these *Publications*. I there stated that I had examined *Capella* on several afternoons early in June, 1900, with the 36-inch refractor without obtaining any visual evidence of its being a double star. The result then obtained was not regarded as conclusive, for the seeing, though good, was not excellent, according to our standards.

On the nights of August 2d and 5th, 1900, I made further examinations with the same instrument, using powers of 1000, 1500, 1900, and 2600. With all these powers the star appeared round. On these dates the seeing was excellent, and stood all these powers perfectly. On the last date the seeing was perhaps the best. With conditions such as then prevailed an elongation due to a distance of a tenth of a second would have been readily perceptible with the lowest power used, and a considerably smaller distance would have given an unmistakable elongation with the higher powers. On the last date glass color-screens of various shades were used a part of the time to reduce the light. Mr. PERRINE at this time also made careful examinations with all of the powers without detecting any elongation.

According to the elements of the orbit of this binary as derived from the spectroscopic observations, the most favorable dates for detecting an elongation visually are about April 15th, June 6th, July 28th, September 18th, and November 9th, 1900, and April 14th, June 5th, July 27th, September 17th, and November 8th, 1901. On account of the orbit's being nearly circular, the apparent distance has nearly its maximum value for a few days on either side of the dates given.

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* Lick Astronomical Department of the University of California.

I have recently examined *Capella* again on two good nights. At the time of the last examination, August 2, 1901, the seeing was excellent and all the powers mentioned above were successively used. Glass color-screens of different shades were used at times to reduce the light. At the time of this examination the zenith distance of *Capella* varied from 45° to 38°. With all powers the central disc of the star's image was sharply defined, very small, and apparently perfectly round.

W. J. HUSSEY.

TIMES OF THE ELONGATIONS OF *MIMAS*.

While making measurements of the relative positions of the inner satellites of *Saturn* during the present summer, I noticed that *Mimas* reached its greatest eastern and western elongations about 4.2 hours earlier than the predicted times given in the American Ephemeris. On writing to Dr. HARSHMAN, Director of the Nautical Almanac Office, in reference to the matter, he informed me that the predicted times were based upon Professor HALL'S elements. He also furnished me the systematic corrections necessary to reduce the times of elongation as derived from Professor HALL'S elements to those derived from Dr. H. STRUVE'S elements, as follows:—

1900.0	$-3^h.68$
1901.0	-4.02
1902.0	-4.37
1903.0	-4.72
1904.0	-5.06

The times of elongation of *Mimas* for the years 1900, 1901, 1902, and 1903, as given in the American Ephemeris, are based upon HALL'S elements. Those for 1904 are based upon STRUVE'S elements. From my measures it appears that STRUVE'S elements represent the motion closely.

W. J. HUSSEY.

DUPLICITY OF *66 TAURI* AND OF THE PRINCIPAL COMPONENT OF Σ 2339.

While examining *66 Tauri* with the 12-inch telescope, February 24, 1900, I discovered that it is a close pair. Several months passed before I measured it, and it is only recently that second and third measures have been obtained. These measures give—

1900.920	22°.7	0″.26	5.8	6.0
1901.584	205 .3	0 .24	6.0	6.0
.658	23 .6	0 .25	6.0	6.0

The magnitudes of the two components are so nearly the same that I have not been able to determine the quadrant with certainty.

66 Tauri is a naked-eye star. Its proper motion has been determined, and, according to AUWERS, is given by the equations—

$$\mu = -0^s.0027, \qquad \mu' = -0''.004.$$

On account of the character of the pair and by reason of its proper motion, it is probable that *66 Tauri* is a binary.

I have recently found the principal component of Σ 2339 to be a close pair. The star did not appear to be quite round to me with the 12-inch telescope. On this account I examined it with the 36-inch refractor, which clearly showed it double. I have made the following measures of it:—

1901.603	85°.2	0″.20	8.0	8.2
.608	87 .0	0 .18	. .	. .
.623	86 .7	0 .20	8.0	8.2

The components of this pair are a little unequal in brightness, so that the quadrant is readily determinable.

I have referred these stars to Professor BURNHAM, who has kindly looked them up for me, and states that they are both new.

W. J. HUSSEY.

OBSERVATIONS OF THE SPECTROSCOPIC BINARY *η PEGASI*.*

The binary character of *η Pegasi* was discovered in August, 1898, from observations made with the Mills spectroscope, and announced in the *Astrophysical Journal* for October, 1898. It was the first one of some thirty-five spectroscopic binary systems discovered in the past three years with this efficient instrument. As a basis for determining the orbit of the bright component of this system, the following velocities in the line of sight were observed:—

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* From Lick Observatory Bulletin, No. 5

No.	Date. Greenwich M. T.			Velocity. Kms.
1	1896,	Aug.	27.8,	+ 7.10
2		Sept.	23.7,	+ 5.10
3	1897,	July	8.9,	— 6.37
4		Sept.	28.7,	— 2.21
5	1898,	Aug.	29.8,	+16.54
6			30.8,	+15.62
7		Sept.	4.7,	+16.46
8			15.8,	+15.74
9		Oct.	18.7,	+10.99
10			24.8,	+11.51
11			26.8,	+10.83
12		Nov.	28.7,	+ 6.06
13	1899,	Jan.	23.6,	— 0.84
14		May,	2.0,	— 6.44
15			9.0,	— 5.94
16	1899,	June,	21.0,	— 8.02
17			27.0,	— 8.31
18		July,	26.9,	— 7.14
19		Sept.	6.8,	— 6.81
20		Dec.	19.7,	— 3.86
21			25.7,	— 1.44
22	1900,	May,	14.0,	+10.89
23		June,	7.0,	+14.06
24		Aug.	1.9,	+18.89
25		Sept.	25.7,	+21.40
26		Oct.	9.7,	+20.37
27			24.8,	+19.88
28		Dec.	11.7,	+15.17
29	1901,	May,	9.0,	— 0.18

The period of revolution of the system was early found to be about two years and a quarter. The observations are distributed over more than two complete periods.

The probable error of one observation, ± 0.47 kilometer, determined by Dr. CRAWFORD, is very satisfactory under the circumstances. It is based upon all the observations secured. These include those made in 1896, with a very imperfect camera lens. The first thirteen observations were obtained before the special temperature control was installed. The thirteenth observation was made when the star was low in the west, in the early evening, with the temperature changing rapidly. Experience has shown that observations taken under such conditions are not only useless, but are apt to be harmful, and No. 13 might well have been rejected. It furnishes the largest residual, and its rejection would have reduced very materially the computed probable error of a single observation.

The spectra were measured, in all cases, soon after they were secured, in six different years. The 26th, 27th, and 28th plates were measured and reduced by Dr. REESE, and the remaining twenty-six plates by myself. If they could have been measured in quick succession, by one observer, no doubt the results would yield a much smaller computed probable error, as the personal habits of measurement change appreciably with time.

Messrs. HUSSEY and AITKEN have carefully examined *η Pegasi* with the 36-inch refractor, but have been unable to detect the companion-star.
W. W. CAMPBELL.

1901, July 24.

THE ORBIT OF THE SPECTROSCOPIC BINARY η PEGASI.

[ABSTRACT.]*

This orbit of *η Pegasi* is based upon the twenty-nine observations given by Director CAMPBELL. Of these, several groups have been formed into normal positions by taking the mean of their dates and of their velocities. These groups are Nos. 5, 6, 7, 8; 9, 10, 11; 14, 15; 16, 17; and 20, 21. All of the other observations have been given weight unity, except No. 13, to which, for reasons given by Director CAMPBELL, weight one-half has been assigned.

From the plot of these observations the first approximation to the period was taken to be 815 days. By adjusting the upper and the lower areas to equality by means of a planimeter, the velocity of the center of the mass was found to be $+4.15^{km}$.

Using the formulæ and notation of LEHMANN–FILHÈS, a set of preliminary constants and elements was obtained. From these elements and the residuals resulting from them twenty-one weighted homogeneous observation equations were set up. These were solved by the method of Least Squares and a second set of elements obtained. From the differences between the residuals as found from these elements and from the observation equations, it was seen that the terms involving the second powers of the increments in the differential equations of condition were not negligible. This discrepancy necessitated another solution starting from the second elements, which resulted in the set of Final Elements here given :—

FINAL ELEMENTS.

$K = 14.20^{km}$ $\pm 0.13^{km}$
$e = 0.1548$ ± 0.0106
$\omega = 5^\circ.605$ $\pm 3^\circ.708$
$\mu = 0.007681$ rad ± 0.000020 rad
$= 0^\circ.44009$ $\pm 0^\circ.00117$
$T =$ 1898 June 29.7 ± 8.1 days
$=$ 1900 Sept 25.7
$V_0 = +4.31^{km}$ $\pm 0.10^{km}$
$U =$ 818.0 days ± 2.2 days
$a \sin i = 157{,}800{,}000$

RUSSELL TRACY CRAWFORD.

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* The detailed paper is printed in *Bulletin* No. 5 of the Lick Observatory.

NEW DOUBLE STARS.

Systematic search for new double stars has formed a part of my observing programme for the past two years, with the result, so far, of the discovery of 250 pairs not previously known. Two hundred and three of these pairs have been published in *A. N.* 3635 and 3668, and in *Bulletin* No. 3 of the Lick Observatory. Attention has been called to some of the more important pairs of the first two lists in previous numbers of these *Publications*.

The third list, published in Lick Observatory *Bulletin* No. 3, contains 94 pairs, classified with respect to the distance between their components as follows:—

Under	0″.25	3
	0 .50	23
	1 .00	47
	2 .00	73
Over	5 .00	1

Two of these pairs are formed from the division of the principal component of the known double stars H 846 and Σ 2527.

The measures are:—

A 143.

R. A. $12^h\ 10^m\ 46^s$; Decl. −7° 26′.

A and *B* (New).

1901.27 148°.8 1″.00 9.2–10.3 3^n.

A and *C* = H 846.

1901.26 113°.4 13″.02 9.2–11.5 2^n.

A 159.

R. A. $19^h\ 23^m\ 0^s$; Decl. +20° 28′.

A and *B* (New).

1900.65 335°.0 0″.78 8.4–11.7 3^n.

A and *C* = Σ 2527.

1900.61 18°.3 4″.26 8.4–9.5 1^n.

The two closest pairs in the list are A 162, and A 194, for which I obtain the following results:—

A 162.

R. A. $19^h\ 30^m\ 47^s$; Decl. +23° 15′.

1900.66 144°.6 0″.21 8.2–8.2 3^n.

A 194.
R. A. $22^h\ 57^m\ 28^s$; Decl. $+47^\circ\ 28'$.
1900.94 $97^\circ.7$ $0''.18$ 8.0–8.0 4^n.

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hree he pairs discovered since the lists mentioned above consist of additional components to previously e stars.

sures are as follows: —

A. $19^h\ 7^m\ 43^s$; Decl. $+24^\circ\ 23'$ (1880.0).
A and *B* (New).
1901.35 $288^\circ.6$ $2''.79$ 8.0–13.5 3^n.
A and *C* = Ho. 446.
1901.35 $48^\circ.3$ $5''.32$ 8.0–12.0 3^n.
A and *D* (New).
1901.35 $112^\circ.0$ $33''.6$ 8.0–15.5 1^n.
D and *E* (New).
1901.35 $118^\circ.8$ $5''.38$ 15.5–16.0 1^n.

R. A. $20^h\ 3^m\ 38^s$; Decl. $+35^\circ\ 26'$ (1900.0).
A and *B* = OΣ 398.
1901.53 $77^\circ.3$ $0''.96$ 7.7–9.7 1^n.
A and *C* (New).
1901.53 . $132^\circ.0$ $5''.23$ 7.7–15.0 1^n.

R. A. $20^h\ 7^m\ 25^s$; Decl. $+34^\circ\ 7'$ (1880.0).
A and *B* (New).
1901.41 $206^\circ.2$ $0''.21$ 7.6–7.8 3^n.
AB and *C* = Ho. 121.
1901.40 $17^\circ.0$ $22''.80$ 7.0–11.5 2^n.

September 5, 1901.   R. G. AITKEN.

SOME RECENT RESULTS SECURED WITH THE MILLS SPECTROGRAPH.*

The results given below are a few of those recently established by the Mills spectrograph, used in connection with the 36-inch refracting telescope. The majority of the photographs upon which the results depend were made by Assistant Astronomer W. H. WRIGHT, and the remainder by DR. REESE and myself.

June 20, 1901.   W. W. CAMPBELL.

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* Reprinted from *Bulletin* No. 4 of the Lick Observatory.

I.—A LIST OF SIX STARS WHOSE VELOCITIES IN THE LINE OF SIGHT ARE VARIABLE.

The following six spectroscopic binaries, discovered with the Mills spectrograph, are additional to the twenty-five already announced.

π *Cephei* ($\alpha = 23^h\ 05^m$; $\delta = +\ 74^\circ\ 51'$).

The binary character of this star was suspected in August, 1899, from the fact that the approximate measures and reductions of the first and third plates showed a range of four kilometers in the observed velocities. Later plates confirmed the fact of the variation. The observations to date are as follows:—

Date.			Velocity.
1899	August	8	$-\ 33^{km}$
	August	23	$-\ 36$
	August	29	$-\ 37$
1900	October	7	$-\ 5$
	December	24	$-\ 23$

o_1 *31 Cygni* ($\alpha = 20^h\ 10^m$; $\delta = +\ 46^\circ\ 26'$).

The variability was detected in July, 1900, from the third plate.

Date.			Velocity.
1899	June	20	$-\ 12^{km}$
	July	2	$-\ 11$
1900	July	30	$-\ 3$
	August	12	$-\ 3$
	October	7	$\pm\ 0$
1901	June	5	$+\ 3$

This star was discovered to have a composite spectrum by Harvard College Observatory. [*Annals H. C. O.*, XXVIII, 93.]

ξ *Piscium* ($\alpha = 1^h\ 48^m$; $\delta = +\ 2^\circ\ 42'$).

The variable velocity of this star was discovered in September, 1900, from measures of the third plate.

Date.			Velocity.
1899	September	5	$+\ 25^{km}$
	September	19	$+\ 27$
1900	September	17	$+\ 33$
	December	26	$+\ 35$

τ *Persei* ($\alpha = 2^h\ 47^m$; $\delta = 52^\circ\ 22'$).

The variable velocity of τ *Persei* was discovered from the th plate of its spectrum in October, 1900.

Date.			Velocity.
1898	October	26	$+10^{km}$
	November	14	$+8$
	November	28	$+8$
1900	October	15	-2
	October	31	-3
	December	17	-4

as discovered at Harvard College Observatory that this s a composite spectrum. [*Annals H. C. O.*, XXVIII,

ξ_1 *Ceti* ($\alpha = 2^h\ 08^m$; $\delta = 8^\circ\ 23'$).

The variable velocity of this star was discovered from the plate in October, 1900.

Date.			Velocity.
1897	October	27	-9^{km}
1898	October	10	-7
	October	17	-8
1900	October	29	$+4$
	December	4	$+1$

ε *Hydræ* ($\alpha = 8^h\ 42^m$; $\delta = +6^\circ\ 48'$).

The variable velocity of this star was detected from the third plate in December, 1900.

Date.			Velocity.
1899	November	27	$+43^{km}$
	December	26	$+43$
1900	December	3	$+35$
	December	24	$+40$
1901	April	23	$+32$

II.—RADIAL VELOCITIES IN THE SYSTEM OF δ *EQUULEI.*

This is one of the most interesting double stars known, discovered by OTTO STRUVE in 1852. Its period of revolution was supposed to be 11.4 years. It was placed on the observing program for the Mills spectrograph, and its radial velocity was observed as follows:—

Date.			Velocity.
1900	June	25	-14^{km}
	July	9	-13

No peculiarities, such as doubling of the lines due to the two components, were apparent in the spectrum. This result was anticipated, as the two components were known to be moving approximately parallel to the line of nodes of their orbit; that is, at right angles to the line of sight.

In September, 1900, Assistant Astronomer AITKEN'S observations of this star showed that the long-accepted orbits were unsatisfactory [*Publ. A. S. P.*, XII, 255–7]; and Astronomer HUSSEY'S investigations rendered it probable that the period is only 5.7 years [*Publ. A. S. P.*, XII, 215–223].

Special efforts have been made to secure spectrographic observations of δ *Equulei* this spring, with a view to solving the difficult question of the star's period. A few successful negatives have been obtained in the past two months. The spectra of the two components are clearly shown, with displacements corresponding to a relative velocity at present of about 35 kilometers per second. If the distance between the corresponding lines decreases, and vanishes, in the next few months, we shall have conclusive proof that the period of the star is in the vicinity of 5.7 years; otherwise, the longer period should have the preference.

III.—RADIAL VELOCITIES IN THE SYSTEM OF *POLARIS*.

It was discovered in August, 1899, from observations made with the Mills spectrograph, that α *Ursæ Minoris* (*Polaris*) is a triple star. A few observations secured that month showed at once that the bright component was moving around the center of mass of itself and an invisible companion in a period of about 3 days 23 hours. Six observations secured in 1896, extending over three months, were best satisfied on the assumption that the period is 3^d 23^h 15^m. A comparison of the 1896 and 1899 observations furnished a period of 3^d 23^h $14^m.3$.

The velocity of the center of mass of this system varied from — 18.0^{km} per second in 1896 to — 11.8^{km} in 1899; thereby affording proof that this system was revolving around the center of mass of itself and a third body in a relatively long period of time.

Further observations have been secured at intervals since August, 1899, for the purpose of detecting the first evidence of change in velocity of the center of mass of the short-period system. Changes suspected in the latter half of 1900 have now become certain: the velocity of the center of mass of the binary system has varied from -11.8^{km} in 1899 to about -13.5^{km} at the present time.

The period of the binary system, $3^d\ 23^h\ 14^m.3$, deduced in 1899, seems to satisfy recent observations perfectly.

IV.—THE RADIAL VELOCITY OF α *PERSEI.*

Mr. H. F. NEWALL, from observations made at Cambridge, England, has announced [*The Observatory*, December, 1900] that the velocity of α *Persei* is variable. His results lie between -4 and $+8^{km}$ per second, and were secured in the years 1899 and 1900.

The following table contains all the Mills spectrograph observations of this star, with the time-intervals between successive dates:—

Date.	Velocity.	Interval.
1896 November 11	-2.0^{km}	
November 12	-1.8	1 day
1897 January 19	-3.5	68
1898 July 12	-2.1	539
1899 September 25	-1.5	440
1900 December 16	-2	447
December 26	-2	10
December 30	-2	4
December 30	-3	0
1901 January 13	-2	14

These ten observations, made in six different years, exhibit a range of only two kilometers. Since this is about the usual range for such stars, due largely to changes in the observer's personal habits in measuring the plates, we may say that these observations afford no evidence of variable velocity.

V.—THE RADIAL VELOCITY OF θ *URSÆ MAJORIS.*

Observations of this star at Pulkowa in the years 1894 and 1896 by Dr. BELOPOLSKY gave results ranging from $+1^{km}$ to $+22^{km}$ per second; and it was announced as a spectroscopic binary with period of from five to seven days. [*Astr. Nach.*, No. 3549; *Astroph. Jour.*, XI, 383.] Results obtained by the same observer in February and March, 1899, ranging from $+7^{km}$ to $+19^{km}$, were considered by him to furnish no evidence of variable velocity during those months [*Astr. Nach.*, No. 3603].

The Mills spectrograph observations, as published below, do not indicate variable velocity.

Date.		Velocity.
1897 November	16	+ 15 ± km
1899 December	18	+ 16
December	24	+ 15
December	27	+ 14
1900 January	30	+ 14
1901 January	27	+ 14

VI.—THE VARIABLE VELOCITY OF δ *ORIONIS* IN THE LINE OF SIGHT.

The variable velocity of this star was discovered by M. H. DESLANDRES from observations made with the great Meudon refractor. This star is not on the programme for the Mills spectrograph, as its lines are very broad and unsuitable for accurate measurement. However, Mr. WRIGHT has secured three observations, as below, which confirm M. DESLANDRES' discovery.

Date.		Velocity.
1900 August	12	$+ 3^{km}$
August	21	+ 51
September	17	— 69

OBSERVATIONS OF THE SATELLITES OF *URANUS* IN 1900 AND 1901.

The present great south declination of *Uranus* makes observations of its faint satellites difficult in northern observatories even under the best conditions, and worthless when the conditions are poor. On this account a comparatively small number of measures, especially of the two inner satellites, *Ariel* and *Umbriel*, was secured during the last two oppositions of the planet. For of the nights when the 36-inch telescope was available to me, I used for this work only those on which the satellite measured could be seen continuously during the time of observation, and on which the image of *Uranus* was sufficiently steady and well-defined to permit accurate bisections to be made with the micrometer-wire.

The detailed observations with notes on the relative brightness of the satellites and a comparison of the observed positions with those derived from NEWCOMB's Tables (Washington Observations for 1873—Appendix I) are published as *Bulletin* No. 7 of the Lick Observatory.

briel was usually the most difficult of the satellites to see, *itania* the easiest. But on several nights *Ariel* could not seen steadily, though *Umbriel* was measured satisfactorily.

The residuals derived from the comparison with NEWCOMB'S tables indicate that the satellites are slightly in advance of their predicted places, and that their orbits are a little smaller than those given by NEWCOMB.

The average residuals are:—

Ariel	+ 2°.2	− 0''.29
Umbriel	+ 1 .2	− 0 .16
Titania	+ 1 .45	− 0 .18
Oberon	+ 0 .7	− 0 .13

tion that these quantities represent the error the probable error of a single observa- eac he following result:—

	± 1°.2	± 0''.16
el	± 1 .1	± 0 .18
a	± 0 .6	± 0 .20
O	± 0 .3	± 0 .18

bles are based upon observations made with e 26-inch refractor of the U. S. Naval Observatory in 1874 and 1875. That they represent observations made a quarter of a century later as closely as is indicated by the residuals here given is sufficient commentary upon the skill and care with which they were constructed, and upon the accuracy of the observations on which they were based.

R. G. AITKEN.

OBSERVATIONS OF THE SPECTROSCOPIC BINARY *CAPELLA*.*

The first-magnitude star *Capella* was discovered to be a spectroscopic double star, early in August, 1899, from an examination of the plates of its spectrum secured with the Mills spectograph in 1896. Announcement of the fact was made to the Astronomical and Astrophysical Society of America at the meeting of September 7, 1899, and in the *Astrophysical Journal* for October, 1899.

Independent discovery of its binary character was made by Mr. H. F. NEWALL, of Cambridge, England, in November, 1899, and announced in the *Monthly Notices Royal Astronomical Society* for November.

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*From Lick Observatory Bulletin, No. 6.

The spectra of the two components are distinguishable on most of the plates, the exceptions being those taken when the radial velocities of the two were nearly equal, producing a superposition of the two sets of lines. The spectrum of the principal star is of the solar type, whereas that of the secondary is intermediate between the solar and Sirian types.

The velocities of the principal component, as observed with the Mills spectrograph, are given by the following table:—

No.	Date. Greenwich M. T.	Velocity. Kms.
1	1896, Sept. 1.036	+36.4 c.
2	17.005	53.8 c.
3	Oct. 4.003	50.3 c.
4	6.029	46.9 c.
5	Nov. 12.865	4.2 c.
6	1899, Aug. 12.999	48.3 c.
7	27.052	26 1 c.
8	Sept. 12.950	5.7 w.
9	20.006	5.1 w.
10	20.919	3 5 w.
11	20 933	5.4 w.
12	25.909	6.6 c.
13	Oct. 3.988	14.8 c.
14	16.912	32.9 c.
15	16.929	32.0 c.
16	31.892	52 0 c.
17	1899, Nov. 6.026	+54.8 c.
18	27.952	43.2 w.
19	27.966	44.0 w.
20	Dec. 3 720	35.2 c.
21	18.648	12.6 w.
22	24.882	7.7 w.
23	1900, Jan. 10.649	7.7 c.
24	21.740	21.7 w.
25	Feb. 11.724	50.0 w.
26	26.726	55.2 w.
27	26.740	54.8 c.
28	Aug. 2.012	3.6 c.
29	Sept. 19.944	55.5 c.
30	24.950	53.9 c.
31	27.005	53.7 c.

[Measures of the plates by CAMPBELL and WRIGHT are indicated by c. and w. respectively.]

The presence of the second component's spectrum interferes considerably with the measures of that of the first component, and the probable error of a single observation, ± 0.50 kilometer, deduced by Dr. REESE, is as small as could be expected. Measures of the speed of the second component are somewhat uncertain, but an estimated range of from − 3 to + 63 kilometers will not be far from the truth. The masses of the two components are therefore as 1.26 to 1.

The solar-type component is estimated to be half a magnitude brighter, photographically, than the bluer component. In the visual portion of the spectrum the solar component is probably at least a whole magnitude the brighter of the two.

Inasmuch as the spectroscope takes account of the component of speed in the line of sight, and is powerless to measure the component at right angles to the line of sight, the spectroscopic orbit is determinate in form, but indeterminate in size. The inclination of the orbit-plane remains unknown. The minimum orbit capable of satisfying the observed velocities corresponds to the case of the orbit-plane passing through the observer. In this case, the maximum distance between the two components would be about 85,000,000 kilometers; and, if ELKIN'S value of the parallax of *Capella*, 0".08, is correct, the angular separation of the components, as viewed from the solar system, would approximate 0".045 when passing through the nodes. Such an orbit would give rise to eclipses every fifty-two days. No variations in the brightness of *Capella* having been observed, it is said to assume that the orbit-plane makes an appreciable angle with the line of sight.

In the case of a great number of orbit-planes distributed fortuitously, the most probable value of the angle between the normal to the orbit-plane and the line of sight would be 60°. The corresponding angular separation of the components at the nodal points would be about 0".052. In case this angle should be 30°, the corresponding separation would be 0".09.

The question as to whether *Capella* could be observed as an ordinary double star early arose. It was most carefully examined with the 36-inch refractor on several occasions in 1900 and 1901 by Messrs. HUSSEY and AITKEN, and on one occasion by Mr. PERRINE; but neither duplicity nor elongation could be detected. Their observations were made under the most favorable conditions, and we may conclude that the angular separation of the components is less than 0".06.

A discussion of the probable masses of the components with reference to the mass of our Sun seems to be futile, on account of the impossibility of harmonizing the best available data for the parallax and brightness of *Capella*, the brightness of our Sun and the angular separation of the components.

1901, July 25. W. W. CAMPBELL.

A DETERMINATION OF THE ORBIT OF *CAPELLA*.

[ABSTRACT.][*]

The computation is based on the thirty-one observations of the velocity in the line of sight of the solar-type component given in the preceding note. The method of computing the orbit is exactly that given by LEHMANN-FILHÉS (*A. N.* 3242), except that in the equations of condition the correction to the velocity of the center of mass of the system is introduced as a sixth unknown, with coefficient unity. The period, 104.1 days, was assumed as best agreeing with the observations, and the observed velocities were plotted as functions of the time interval after the next preceding minimum, assuming September 18.9, 1899, as a time of minimum. A smooth curve was drawn through the points so obtained, and by means of a planimeter the line representing the velocity of the center of mass of the system was drawn so as to inclose equal areas with the portions of the curve above it and below it. The other requisite quantities were then obtained in the way shown in the article already cited. From the set of provisional elements thus found, an ephemeris was computed after first combining certain of the observations in pairs so as to form in all twenty-seven normal places. From the residuals derived by comparing the observations with this ephemeris, equations of condition were set up and solved in the usual manner.

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[*] The complete paper is printed in Lick Observatory *Bulletin*, No. 6.

The probable error of a single observation was found to be ± 0.50 kilometers per second. The final values of the elements with their probable errors are:—

$\mu = 0.060403$ ± 0.000014 radians
$\omega = 117^\circ.3$ $\pm 18^\circ.3$
$T = -17.4$ days ± 5.3 days, the actual date being Sept. 1.5, 1899
$e = +0.0164$ ± 0.0055
$K = 25.76$ ± 0.12
$U = 104.022$ days ± 0.024 days
$a \sin i = 36{,}847{,}900$ kilometers
$V = +30.173$ ± 0.104 kilometers per second

The great uncertainty in the values of ω and T is due to the fact that the orbit is nearly circular. The probable errors of the other quantities are small in view of the difficulty in measuring the spectrum of this star.

It will be recalled that VOGEL and SCHEINER photographed the spectrum of this star from October 6, 1888, to September 15, 1889, but failed to detect its binary character, their spectroscope being apparently incapable of resolving its composite spectrum. By carrying back the period of 104.022 days to 1888 and 1889, their observations can be compared with the orbit. It is found that their plate, number 19, was taken at a time when the relative velocity of the two components was about zero. This plate they marked "excellent." Four other plates, numbered respectively 14, 15, 18, and 67, and marked "very good," "good," etc., were taken at times when the velocity of the solar component relative to the center of mass was nine kilometers or less. One plate, number 95, is marked as rather poor except for a good Hγ line, although the velocity of the solar component relative to the center of mass was only six kilometers. With this exception all plates marked "verwaschen," "uncertain," etc., were taken when the relative velocity of the two components was very large, and therefore the two spectra were very much separated, so as to cause a blurring of the composite spectrum.

JULY 25, 1901. H. M. REESE.

SCIENTIFIC VISITORS TO THE LICK OBSERVATORY.

The Lick Observatory was favored with visits from the following persons, returning to their homes from the Sumatra eclipse stations: —

F. W. DYSON, Esq., F. R. S., Chief Assistant in the Royal Observatory, Greenwich.

Dr. W. T. HUMPHREYS, of the Department of Physics, University of Virginia.

Dr. GILBERT, of the Department of Physics, Lehigh University.

Professor Dr. A. A. NIJLAND, Director of the Observatory, Utrecht, Holland.

Dr. J. H. WILTERDINK, Astronomer in the Royal Observatory, Leiden, Holland.

Professor and Mrs. D. P. TODD, of Amherst College.

W. W. C.

ASTRONOMICAL TELEGRAMS.

(*Translation.*)

CAMBRIDGE, MASS., Aug. 6, 1901.

To Lick Observatory: (Received Aug. 7, 9 P.M.)

WILSON, at Northfield, Minn., telegraphs that he observed ENCKE'S periodic comet on its return on August 5.8924 G. M. T. in R. A. $6^h\ 2^m\ 2^s.8$; Decl. $+\ 31^\circ\ 42'\ 30''$.

(Signed) E. C. PICKERING.

[A cablegram from Kiel, giving a sweeping ephemeris of ENCKE'S comet computed by THONBERG was received at the Lick Observatory on August 5, 1901, at 4 P. M.]

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

Mr. FREDERICK H. SEARES, who, while Instructor in Astronomy in the University of California, took an active part in the conduct of the affairs of the Astronomical Society of the Pacific, has been elected Professor of Astronomy in the University of the State of Missouri. Professor SEARES has been studying in Berlin and Paris during the past two years.

On September 5th the students in astronomy at the University of California enjoyed an "astronomical talk" by Professor DAVID P. TODD, of Amherst College, who is passing through California on his return from the Island of Singkip, where the last solar eclipse was observed. Professor TODD reports that clouds unfortunately interfered, and that his programme of work was therefore only partially carried out.

"Some Advances made in Astronomical Science during the Ninteenth Century," is the title of an address, printed in *Science* for July 5th, recently delivered at the University of Pennsylvania by Professor C. L. DOOLITTLE.

A new astronomical observatory with increased equipment, including the equatorial telescope which formerly belonged to the late Judge NAPP, of New Jersey, is being erected at Lincoln University, Pa. This will be used mainly for purposes of instruction under the directorship of Professor WALTER L. WRIGHT, Jr., who has for a number of years been in charge of the department of mathematics at that institution.—*Science, August 9th.*

The Council of the Astronomische Gesellschaft has undertaken the preparation of a new Catalogue of Variable Stars and has delegated the conduct of the work to a committee consisting of Professors DUNÉR, HARTWIG, MÜLLER, and OUDEMANS. The committee request observers of variable stars who have considerable unprinted series of observations which would be useful in the correction of elements either to publish them soon or to communicate them to the member of the committee in charge (Professor G. MÜLLER, Potsdam Observatory).

committee also announces that it will from the present
undertake the definitive notation of newly discovered vari-
as soon as their light-fluctuations are certainly ascertained.
will shortly be published of the names of variables found
ent years which have heretofore remained unnamed.

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ience for August 9th contains a review of the *Astronomischer*
ericht, by Professor GEORGE C. COMSTOCK, from which
e quote the following introductory historical statement:—

> "
> is series of annual volumes, whose somewhat cumbrous title is
> bbreviated to the symbol *A J B*, owes its inception to its
> fessor WISLICENUS, who in September, 1898, submitted to
> sche Gesellschaft a well-elaborated plan for a year-book
> ve both as an annual summary of current astronomical
> s a bibliography sufficiently complete for the use of
> r investigators. The proposal was favorably received
> not only gave its official sanction and pecuniary
> rtaking, but also appointed a committee, consisting
> ER, BRUNS, and MÜLLER, to confer with the editor
> the future volumes and the manner of their arrange-
> ment."

ENCKE'S periodic comet was well seen at this observatory at 3^h 45^m this morning, August 14, 1901. It was then in α, 6^h 58^m and in $+\delta$, 30° 34′, with rapid motion toward the southeast. The comet was quite large, faint, diffuse, and presented a minute trace or condensation of light, supposed to be a nucleus. The light was white, sky clear, air steady, and the observation was considered satisfactory. EDGAR L. LARKIN, Director.

MOUNT LOWE OBSERVATORY, CAL.,
August 14, 1901.

In a work entitled "Ueber die Ursache der Nordlichter" the Swedish chemist S. ARRHENIUS advances a theory in explanation of the phenomena of the Aurora Borealis and of the solar repulsion of comets. The work is reviewed at length by A. W. AUGUR in the June number of the *Astrophysical Journal*.

The explanation has for a basis the electromagnetic theory of CLERK MAXWELL who proved that in a medium in which electromagnetic or light-waves are propagated, a pressure is produced in the direction of propagation which, at any point, is numerically equal to the total energy per unit volume.

Solar repulsion of the tails of comets, and the apparent ejection of matter from the Sun to form the corona and solar projections, have long puzzled scientists as seeming exceptions of the law of gravitation. KEPLER attempted the first explanation, basing his hypothesis on the emission theory of light, supposing that the matter might be repelled by the impact of the corpuscles. NEWTON accounted for the phenomenon by supposing such a difference in the density of the surrounding medium as causes the ascension of hot air and smoke. EULER, in the eighteenth century, held that light-waves, which he supposed to consist of longitudinal vibrations in the ether, were competent to produce repulsion. This view was so severely criticised that it was soon abandoned. Nevertheless, if MAXWELL'S electromagnetic theory of light be accepted, it appears that EULER was, in the main, right.

A calculation of the radiant energy of the Sun is given, the result being equal to 592×10^{-10} gram-centimeters at the distance of the Earth. At the surface of the Sun this is much greater, being equal to 2.75×10^{-3} grams per square centimeter. This pressure is always away from the Sun, and since the weight of a body at the Sun is 27.47 times its weight at the Earth, a body of unit density and a cube of one centimeter, suspended so that its lower surface were perpendicular to the Sun's rays, would lose about one ten-thousandth part of its weight. If the body were more or less transparent a deduction would have to be made for the light transmitted; but if the body were a perfect reflector the effect would be doubled; so perhaps computations based on the assumption that all radiations are absorbed will be near the truth.

An assumption is then made of the size of the particles which could be acted on by the Sun's rays to effect a total loss of weight. According to BREDICHIN, the matter composing the tails of comets is, at perihelion, repelled from the Sun with a force of 1.5 to 18.5 times its weight. Assuming that the tails of comets are composed of gaseous hydrocarbons whose density could hardly exceed 0.8, the computed diameter of the particles to be thus repelled would lie between 0.1μ and 1.25μ. Such particles would be larger than simple molecules, as micro-organisms of a diameter not greater than 0.3μ have been observed, which, being of complicated organic molecules, are larger than the simple inorganic particles.

Upon this theory is based explanation of the origin and behavior of comets. As a comet approaches the Sun, there is developed on the side toward the Sun an extension of the coma. This is accounted for by supposing that the head of the comet is composed of solid or liquid hydrocarbons of relatively high boiling-point, which are vaporized under the intense heat of the Sun; while the particles are comparatively large they fall towards the Sun, but with their further dissipation they will be repelled and form part of the tail. If the nucleus is heterogeneous, particles of many sizes may be formed, which, by their varying degrees of repulsion, may give rise to several distinct tails, as in the comet of 1774.

A variation in size of the particles explains the fact that the repulsion of the tail is not always proportional to the inverse square of its distance from the Sun. Comets are more numerous and brighter in years when sun-spots are plentiful or the times when the solar activity was at a maximum. This means the repulsion of "cosmic dust" into space, which particles may aggregate till they again fall to the Sun in the form of comets. This "cosmic dust" may account for the phenomena of the solar corona and the Zodiacal Light.

It is almost certain that these particles would be highly electrified, and developing cathode and Rœntgen rays, would ionize the surrounding gases. The negative ions would form centers of condensation for the "cosmic dust," which, leaving the Sun and the positive ions behind, would pass outward into space. The sunny side of the Earth would receive a constant stream of negatively charged particles which would remain in the upper air. The atmosphere would be most strongly charged in the direct line between the Earth and the Sun, and in this region cathode rays might be developed. Under the action of the ultra-violet light, which would render the air conducting, the charges would be gradually conducted toward the less illuminated regions to the north and south.

This theory of the formation of cathode rays overcomes the objections raised to the statements of Dr. PAULSEN, who concluded they were the same as the Aurora Borealis, on account of their similarity in essential characteristics.

Since cathode rays tend to follow the lines of force in a magnetic field, the rays will, near the equator, lie in the upper air where the lines of force are parallel with the surface of the Earth.

At the poles, where the lines of force dip towards the Earth, the cathode rays in following, will reach denser strata of air, which produces the illumination of the Aurora.

Practically all the known facts concerning the Aurora harmonize with the theory that the light is produced by the cathode rays which arise from negatively electrified particles repelled from the Sun. The remarkable identity of the eleven-year periods of the Aurora and sun-spots, the annual, monthly, and daily variations in the number and intensity of the Aurora following closely the variations in the positions of the Sun, and the intensity of its light may all be much more satisfactorily explained by this theory than perhaps by any other.

The variability in light of *Eros* forms the subject-matter of Harvard College Observatory Circular No. 58, and in it Professor E. C. PICKERING reviews the theories advanced as an explanation of the variability.

If, as it seems probable, we assume that the variation is due to the rotation of the planet, we can, from measures of its light, determine the time of rotation and the direction in space of the axis of rotation.

Four corrections must be made to the observations: (1) for the velocity of light; (2) for the distance of the Sun and the Earth; (3) for phase; and (4) for the direction of the axis of rotation.

Of the two explanations advanced,—(1) that the variation is due to one side of the planet being darker than the other, and (2) that it is due to the rotation of two bodies,—Professor PICKERING seems to lean towards the latter. In the first case, the successive maxima would always have the same intensity, and would succeed each other at equal intervals, which would be equal to the period of revolution, and this is not true. In the second case, if the two bodies differed in diameter, the successive maxima and minima might have unequal intensities; and if the orbit were elliptical, the intervals between them would be alternately long and short. This seems to be the case with *Eros*.

On the other hand, if the variation in light is caused by two similar bodies alternately eclipsing each other, it is difficult to see how more than half of the light can be cut off in each case, and the minima be more than three quarters of a magnitude fainter than the maxima. It then becomes necessary to assume that the two bodies are of unequal brightness, that they are elongated, or that we have a single body, of the shape of a dumb-bell. Some observers have found the minima two magnitudes fainter than the maxima. To account for this, we should be obliged to assume that one axis of the body was six times as long as that at right angles to it. Observations show that the light of *Eros* is continually varying; while if the case were that of a simple eclipse, as in the stars of the *Algol* type, we should expect that it would retain its full brightness for a large portion of the time.

Photographs of *Eros* taken in 1893, 1894, and 1896, furnish material for determining the constants mentioned above. Those of 1893 and 1894, which were exposed an hour or more, and in
ch the planet trailed upon the plate, showed little variation
. The plates taken in 1896 give more conclusive evi-
f changes. In 1898, photometric measures were made,
they furnish an accurate determination of the times of
m and minimum and of the range for that epoch.
o, a large number of photometric measurements
, but the results have not been analyzed. This
a future "circular." On May 8th, Professor
ERING announced that the variation in the light from the planet had become zero.

The first brief despatches announce that the attempt made by the expedition to Sumatra from the Massachusetts Institute of Technology to photograph the shadow-bands at the time of an eclipse was successful. A writer in *Engineering News* of August 1st thus describes the bands and the apparatus used.

Professor ALFRED E. BURTON, who is in charge of the Sumatra expedition, has associated with him GEORGE L. HOSMER, of the Engineering Department; Mr. HARRISON W. SMITH, of the Department of Physics, and Mr. G. H. MATTHES, a graduate of the institute, now in the U. S. Geological Survey. Before going abroad this party especially studied this shadow-band problem, and devised means for better recording them for later study.

Heretofore these bands have only been observed visually. These quivering bands of light and shade were noted upon the walls of buildings or on the white sand; and the first attempts at record were made by spreading a sheet on the ground upon which sticks were placed to show the direction of the shadows and their movements. A slight advance upon this method was the use of long strips of canvas marked with black lines to facilitate visual measurements of the bands. Sticks painted in alternate colors have also been employed, while an assistant sometimes ran with the shadows, so as to furnish a comparative standard for estimating their velocity. Methods of this kind were used by Professor WILLIAM H. PICKERING, in observing at Granada, Spain, the eclipse of August 29, 1896.

But as these attempts at record are manifestly crude, all theories regarding these shadows, based upon them, are more or less speculative. Professor PICKERING reported that some of the bands were six feet long, and some of unknown length; that some moved at the rate of only six miles an hour, and others at the rate of an express train, and some moved in an undulatory fashion, with the speed of the wind.

He believed that the bands were due to disturbances of the atmosphere, and were not due to the shadow of the Moon, which moves at the rate of a mile a second. He assumed that every star cast its shadow-bands too faint to be seen, and demonstrated this by producing artificial bands on the observatory wall at Cambridge by an electric light located three-quarters of a mile away.

During the eclipse of January 1, 1889, Mr. WINSLOW UPTON observed at Willows, Cal., shadow-bands an inch in width and three or four inches apart, and apparently stationary; but an endeavor to photograph them in the ordinary way under favorable circumstances proved a failure. In recent eclipses long dark bands separated by light spaces have been seen, more or less distinctly, moving rapidly on the ground or on the sides of buildings just before and after totality. At the eclipse of May 28, 1900, an attempt to photograph the bands on a screen failed.

The method used at the last eclipse was planned by Mr. HARRISON W. SMITH before leaving Boston. The new plan is to actually expose a sensitive photographic plate to the bands themselves, letting the bands fall upon it; that is, in place of endeavoring to photograph the bands as they appear on a screen. It was proposed to use a shutter of the form of the Thornton-Picard focal plane shutter. In the preliminary experiments two ordinary curtain-rollers were fixed at the end of a light wooden frame, with an opaque curtain stretched over the rollers, to be rolled up on one roller, and, when released, wound up rapidly on the other by means of a spring. This curtain contained a slot, and was stretched directly above a sensitive plate. When the curtain was released, the slot was drawn rapidly across the plate, which was then exposed to whatever light happened to be falling on the apparatus. If the intensity of light in Sumatra varied sufficiently from point to point to produce visible bands, it would appear that the bands ought to be recorded by this apparatus on the plate. Again, by having two slots in the curtain, one traveling across the plate just after the other, the velocity of the bands could be determined, since the bands on opposite halves of the plate would not join, but would appear displaced relatively to their velocity and that of the moving curtain.

Two sets of apparatus placed at an angle of ninety degrees would record the bands, whatever their direction might be; and if the records obtained in Sumatra are as intelligible as the plan of the apparatus would presume, astronomers will have for the first time accurate data for scientific study of this particularly puzzling phenomenon.

The meeting of the Board of Directors of the Astronomical Society of the Pacific, and the meeting of the Society itself, which were to be held at the Lick Observatory on September 7th, were adjourned, without transacting business, for lack of a quorum.

Obituary Notices.

TRUMAN HENRY SAFFORD, for many years Professor of Astronomy at Williams College, died at Newark, June 12th. From a short account of his life, published in *Science*, July 5th, by Professor HAROLD JACOBY, the following extracts are taken:—

"Born January 6, 1836, at Royalton, Vt., he showed already in his early boyhood the extraordinary arithmetical powers which distinguished him through life; for he could at all times multiply mentally very large numbers, knew off-hand the multiplication-table to 1,000, and most of the logarithmic tables to three figures. At fourteen he is said to have calculated a cometary orbit, and he graduated from Harvard at eighteen. For some years he was observer at that University under BOND, and for a short time was acting director. In 1865 he took charge of the Chicago Observatory, where he began his serious work, the observation of one of the Astronomische Gesellschaft zones. But his work was cut short and his position lost through the great Chicago fire. He then entered WHEELER's astronomical survey in the far West, and worked during several years for the Government scientific bureaus of Washington. It was not until 1876 that he finally settled down for life as Professor of Astronomy in Williams College, Williamstown, Mass.

"Here was done his principal work, which related especially to star-positions and star-catalogues. He made an elaborate discussion of all existing observations of the stars most suitable for determining geographical latitudes of the United States. This resulted in a catalogue of 2,018 stars, which was published by the Engineer's Department, U. S. Army. Later, he made a similar catalogue of 612 stars, and upon it has been based the new boundary between the United States and Mexico. This was published in the report of the Mexican Boundary Commission, Washington, 1898. SAFFORD built at Williamstown a meridian observatory, which is a model of its class. In it he installed a Repsold circle, with which he made extensive observations of the close polar stars. He liked these stars especially, and the unusually lengthy numerical calculations connected with them did not frighten him. He needed no observing list, as his memory never failed to give him the instrumental setting for each of his beloved polars in every possible position of his instrument. These polar observations were collected and published by him in the "Williams College Catalogue of North Polar Stars." . . .

"More striking, perhaps, was his confident prediction, in 1861, of the minute unseen companion of the bright star *Sirius*. Basing laborious calculations on the tiny irregularities in existing observations, he was able to show just where the little *comes* must be. And there it was found in January, 1862, by ALVAN CLARK, of Cambridgeport, Mass., while he was testing the 18-inch glass mounted at Evanston, Ill.

"SAFFORD was a frequent contributor to astronomical and educational publications, and a member of many learned bodies. The Royal Astronomical Society of London honored him with an election as associate, in 1866, when he was but thirty years of age. Great as were his abilities in astronomy, he was yet at his best as a teacher. Those who came under his influence at Williamstown can bear witness to this; his ablest pupils profited most from his stored learning, and some from among them are laboring for astronomy to-day."

GEORGE K. LAWTON.—In the unexpected death of GEORGE F ON, of the U. S. Naval Observatory, a young astrono- eat promise has passed away. The loss to American can be appreciated as yet only by those who had the e to know him intimately. He was born October 20, , and died at Washington, July 25, 1901, after a brief illness welve days, of typhoid fever; and was thus less than twenty- years of age. Under the guidance of his father, Professor LAW of Jackson, Michigan, he had enjoyed from ood exc t educational advantages, and in 1895 gradu- a in classi t the University of Michigan, where he also ed advan astronomical studies under Professor ASAPH e Detroit Observatory. He then spent a year in udy at the University of Chicago, where the honor to be one of his teachers. He showed dis- abilities in the study of celestial mechanics and of higher mathematics. He was afterwards attached to the Observatory of Yale University for a short time, occupied mainly with work on meteors; and then came to the Naval Observatory as one of the regular computers. In 1897 he took the degree of M. A. at the University of Michigan.

While attached to this observatory he participated in all the transit-circle observations of the past five years, much of which has recently appeared in the *Publications of the U. S. Naval Observatory* (Vol. I, New Series). Last year he bore an important part in the observations of the total eclipse of the Sun, at Pinehurst, North Carolina. More recently he took the leading part in the reductions and revision of the *Eros* observations of this observatory, and has been occupied partly with equatorial work. Only a month ago he was permanently assigned to the 26-inch equatorial, and had entered upon researches of great promise.

On account of his extreme modesty, and the arrearages of our publications, his scientific reputation at the time of his death was in no way commensurate with his merits. Yet he was already a member of the American Association for the Advancement of Science, and last year participated in the meeting of the Astronomical and Astrophysical Society of America.

His mind was developed in admirable symmetry and harmony, and his scholarship almost as good in Latin and Greek and general literature as in modern science. He had that happy faculty of cool, quiet judgment, combined with good-nature, which made him adequate to any occasion. Besides possessing scientific and literary talents of a high order, he was of a very high-minded and noble disposition, universally beloved by his associates. Unseen by men, he continually did many acts of benevolence, and bestowed gracious remembrances which add to the charm of life and make us realize that the high types written of long ago have not wholly passed away. He was an active member of St. Thomas's Church in this city, of the Brotherhood of St. Andrew, and of the Alumni Association of the University of Michigan. During his residence here of five years, he became fairly well known in the city, more by the reputation of his high character than by any very extensive mingling with the people. When the writer had to send the saddest of messages to his grief-stricken family, the telegraph operator, who knew him only by reputation, was nearly overcome, and said, "That good man is not long for this world." In all my experience I have never met quite so modest, so noble, and so loving a character.

The sudden death of Mr. LAWTON, almost at the very beginning of what promised to be a brilliant career, has cast a deep gloom over the entire observatory. He was indeed the noblest of the noble, and his place can never be filled.

WASHINGTON, D. C., July 27, 1901. T. J. J. SEE.

ERNST AUGUST LAMP.—On May 10, 1901, Professor LAMP, Astronomer of the German Boundary Commission, died in German East Africa. Professor LAMP was born in Kopperpahl, near Kiel, April 4, 1850. He studied in the universities of Kiel, Berlin, and Göttingen, taking his degree at the last named place in 1874. From 1874 to 1877, he was employed at the Geodetic Institute in Berlin; from 1877 to 1883, second observer at the Kiel Observatory; from 1883 to 1897, first observer in the same institution. Upon leaving the Kiel Observatory in 1897, he was connected for some time with the Royal Geodetic Institute at Potsdam, and later with the Boundary Commission mentioned above.

Professor LAMP's chief astronomical work was upon comets. His numerous observations and orbits have been published in the

Astronomische Nachrichten (volumes 87 to 141). In volumes VII and IX of the *Publications of the Kiel Observatory*, he has published extensive investigations of the orbits of the Brorsen Comet and Comet 1891 I. Besides the comet work, Professor LAMP did considerable with the meridian-circle and considerable of a geodetic nature.

ADOLF CHRISTIAN WILHELM SCHUR, Director of the Royal Observatory, Göttingen, died July 1st of this year. He was born April 15, 1846, at Altona, and early became interested in astronomy through a near relative, A. C. PETERSON, then Director of the Observatory at Altona. SCHUR studied at the Universities of Kiel and Göttingen, taking his degree at the latter place in 1868. He then went to Berlin and, after working for a time under AUWERS and FOERSTER, became an assistant in the Geodetic Institute, where he remained until 1873, when he was called to a position at the Strassburg Observatory. Here he remained until 1886, when he was called to Göttingen to succeed KLINKERFUES in the chair of Practical Astronomy.

While at Strassburg SCHUR was engaged in various investigations with the instruments of the observatory, chiefly with the Fraunhofer heliometer, which was used in the Transit of *Venus* expedition of 1874, of which SCHUR was a member. One of the chief investigations with this instrument was a series of measures on the system of *Jupiter*, which led to an exact determination of the mass of *Jupiter*.

At Göttingen also, SCHUR'S work was chiefly with the heliometer, measurements of the *Præsepe* and of the clusters *h* and χ *Persei* absorbing a large part of his time.

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OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Francisco Rodriguez Rey.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

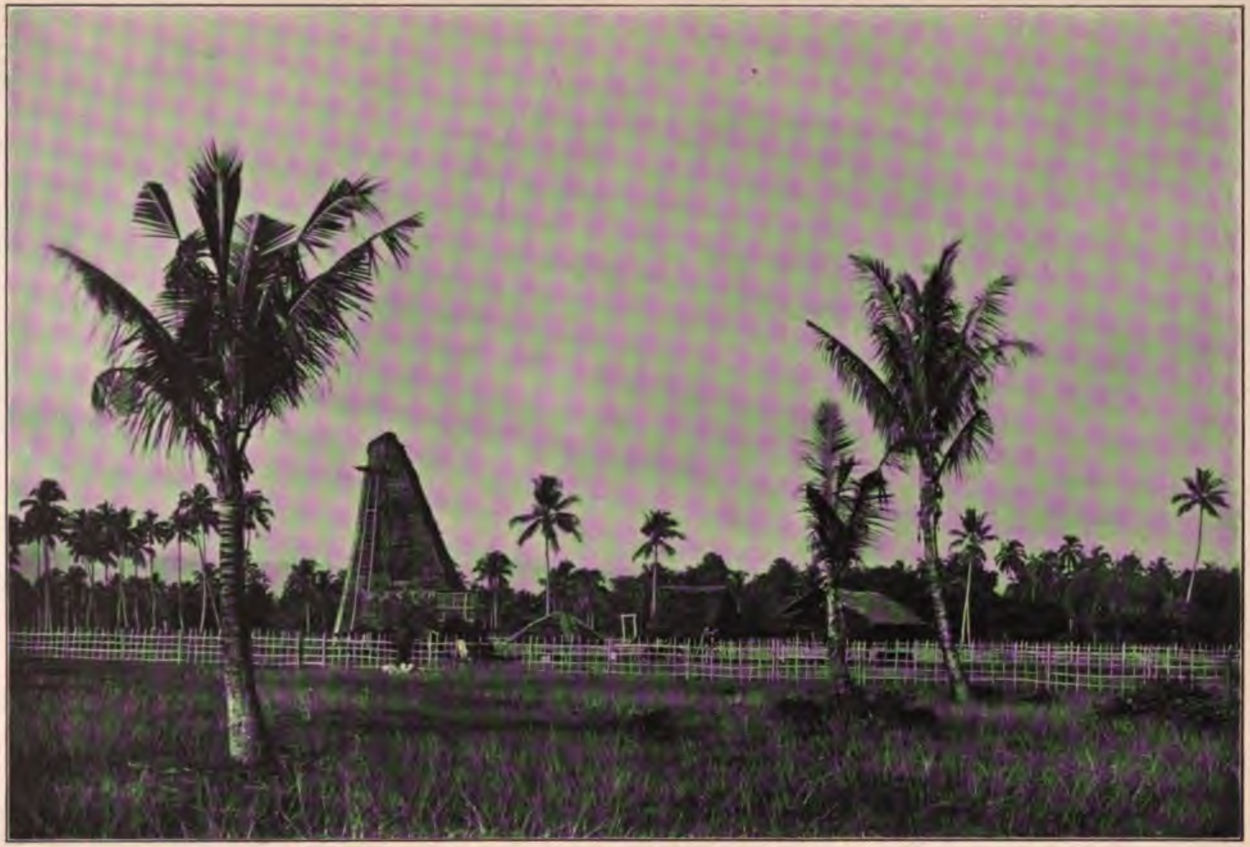
It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)



LICK OBSERVATORY – CROCKER ECLIPSE STATION, PADANG, SUMATRA.

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PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XIII. SAN FRANCISCO, CALIFORNIA, DECEMBER 1, 1901. NO. 81.

THE LICK OBSERVATORY-CROCKER EXPEDITION TO OBSERVE THE TOTAL SOLAR ECLIPSE OF 1901, MAY 17-18.

BY C. D. PERRINE.

In continuation of the expeditions dispatched by the Lick Observatory for the observation of total solar eclipses, one was sent to Sumatra to observe the eclipse of May 17-18, 1901. These expeditions have been made possible by the generosity of private citizens of California who have borne the expenses incident to such undertakings. Inaugurated by Colonel CHARLES F. CROCKER, Regent of the University of California and member of the Committee on the Lick Observatory, they have been continued since his death by his brother, Mr. WILLIAM H. CROCKER, of San Francisco.

Owing to the temporary difficulty of forming future plans after the death of Director KEELER, the organization of the expedition was delayed and the preparations were hurried. While some of the observations planned for were the same as those undertaken at former eclipses, and for which the apparatus needed but slight changes to adapt it to the present eclipse, several investigations required the construction of entirely new instruments. The four telescopes for the intramercurial planet search, two spectrographs, and a polarigraph were constructed and tested in less than a month. The entire staff of the Observatory took up the work, so that, notwithstanding the stormy and unfavorable weather, the equipment was packed and ready for shipment in time for the steamer leaving San Francisco on February 19th for Hongkong.

A rather large equipment of instruments was taken, as previous experience had shown the feasibility of obtaining observers to operate them at or near the station.

The expedition left San Francisco on February 19th, on the steamship "Nippon Maru," of the Toyo Kisen Kaisha. At Honolulu we found the United States transport "Sheridan," and there exchanged greetings with the members of the United States Naval Observatory party.

It was hoped that connection could be made with the North-German Lloyd steamer leaving Hongkong on March 20th for Singapore, but owing to almost continuous heavy weather and head winds as far as Yokohama, we were two days late at the latter port, and reached Hongkong only in time to see the coveted steamer leaving the dock.

Fortunately, however, the "China," a steamer of the Austrian Lloyd Steamship Company, was found to be leaving in two days. After a good run of five days, Singapore was reached on March 27th. The steamer of the Koninklijke Paketvaart-Maatschappij left on the 29th for Batavia. Although having a full cargo of freight and a heavy passenger-list, the agents made room for us, placing the instruments in the second-class cabins. Batavia was reached on March 31st. The through steamer for Europe of the Stoomvaart-Maatschappij Nederland was leaving Batavia on April 3d, stopping at Padang for through passengers and freight only. Again the steamship company was most accommodating, giving us passage on a crowded steamer, and placing the eclipse freight in the baggage-room. Thus we arrived in Emmahaven on April 5th, at daylight, fully ten days earlier than was expected when we left California. Almost the first sight to greet our eyes in the harbor at Emmahaven was the United States steamer "General Alava," with the astronomers of the United States Naval Observatory party on board, they having arrived from Manila the evening before.

From Hongkong to Padang it was noticed that often when the sky near the zenith was fairly clear of clouds they seemed to hover about the land, particularly the mountains, and rain was often seen to fall there. Observations at Padang for several days after arrival showed that the clouds gathered about the mountain-tops and spread thence towards the plains and the ocean. The early mornings were often quite clear, but almost invariably clouds began to gather over the mountains by nine or ten o'clock, and rain was of frequent occurrence in the afternoons. The location, therefore, which seemed to promise best was one as far as possible from any high mountains. Padang is situated in the southern end of a long plain, three or four miles wide, bounded on the west by the ocean, on the south by steep hills, and on the east by the abrupt mountains of the Barisan range, rising to altitudes of 3,000 to 5,000 feet. The probabilities of a clear sky seemed to be as good in Padang as anywhere on the main island. There appeared to be a slight advantage in favor of a station on one of the small low islands forming a chain five to ten miles off the coast, but as the sky was often thick with haze when not cloudy the advantage of such a location was not considered sufficient to counterbalance its disadvantages. It was, therefore, decided to remain in Padang, and a site for the station was chosen on the abandoned racecourse in the northern portion of the city. Its approximate position was—

Longitude $6^h\ 41^m\ 20^s$ East of Greenwich.
Latitude $0^\circ\ 56'$ South.

The programme of observations was entirely photographic, and was as follows:—

1st. Photographs of the prominences and inner corona with the 5-inch Clark lens of 40 feet focal length, after the method devised by Professor SCHAEBERLE.

2d. Photographs of the corona with the Floyd telescope of 5 inches aperture and 70 ± inches focal length.

3d. Photographs of the outer corona with the Pierson* (Dallmeyer) camera of 6 inches aperture and 32.6 inches focal length.

4th. Duplicate photographs of the region near the Sun for the detection of any small planets with orbits interior to that of *Mercury*. These negatives were to be secured with four telescopes of 3 inches aperture and 11 feet 4 inches focal length.

5th. One photograph of the spectrum of the corona, using one light prism, and having the slit east and west across the Sun's center.

6th. One photograph of the spectrum of the corona with a spectrograph similar to the preceding, but having the slit directed north and south, about 2′ east of the Sun's east limb. These two spectrographs were intended to record any Fraunhofer lines in the corona.

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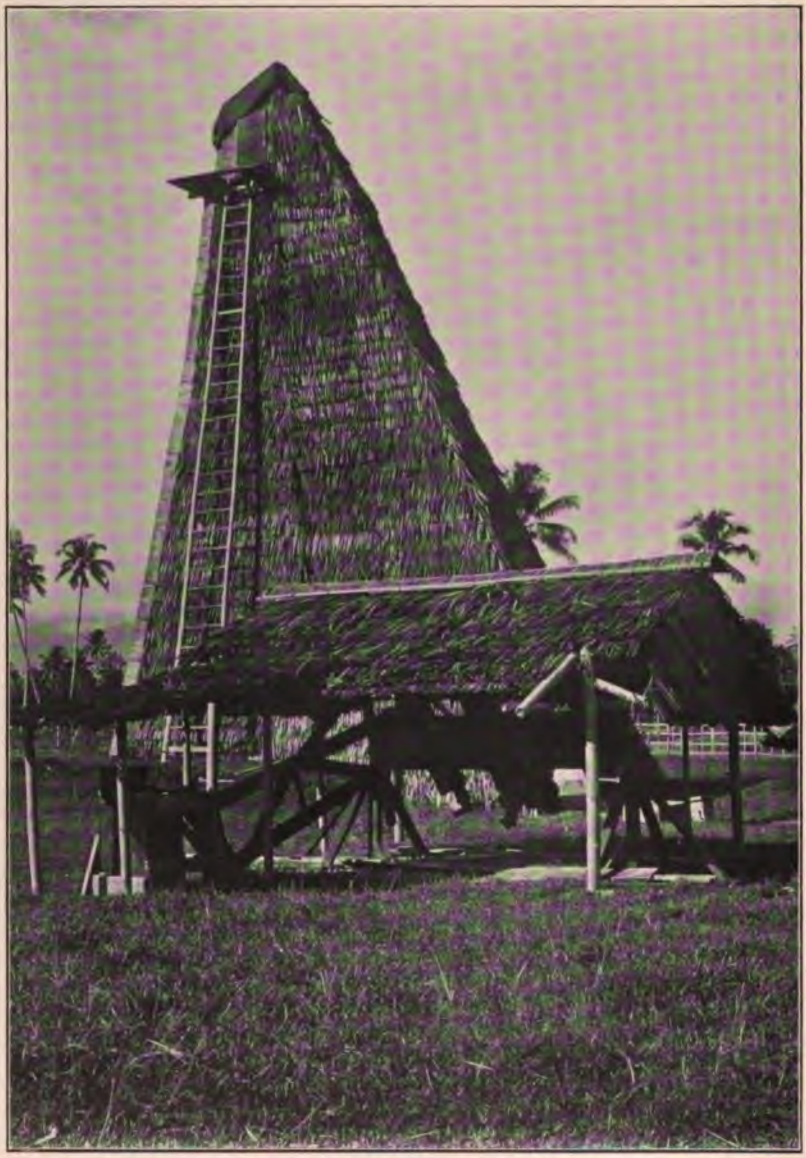
* This Dallmeyer portrait-lens belongs to Hon. W. M. PIERSON, of San Francisco, and has been very kindly loaned by him for a number of eclipse expeditions.

7th. Photographs of the corona with a camera of 20.75 inches focal length, having a double-image prism of one inch aperture placed in front of it. Photographs were to be secured of both images, the position-angle of the prism being changed during the eclipse so as to have its principal plane make angles of 0°, 22½°, 45°, 67½°, and 90°, respectively, with the Sun's equator. Such photographs should show polarization if it exists in a given plane to any considerable proportion.

A large shed of bamboo, covered with palm thatch (atap), was constructed first, serving as a work-shed and as a shelter for partly-mounted instruments. As showers were frequent and came with little or no warning, and as a protection against the sun also, shelters were constructed first and instruments mounted under them afterward. Many of the rains were very heavy — too heavy to be turned by canvas. As the residents of that moist country say, it rains in "strings,"— and the "strings" are frequently almost ropes. After three days of one heavy storm it was noticed that the hollow bamboo fence-posts (just erected) surrounding the camp were overflowing; the deepest cavity in these was ten inches. How much more fell in the three days I do not know.

The tropics seem to be made of bamboo tied together with rattan and protected from the rains by "atap." It was only necessary to buy a small cartload or so of bamboo and atap and a bunch of rattan; out of these materials the expert Malay carpenters constructed everything. Sills, joists, rafters, all parts of framing, were of bamboo tied together with rattan. If a stake was wanted, the bamboo pile furnished it. If a fence was to be built, the same bamboo pile was resorted to, the posts were made of the full-sized thicker ends, the "boards" being long split sections passed through slots cut in the posts. The gate was of bamboo, even to the hinges and catch.

Only a slight elevation was available upon which to build the tower required to support the lens and tube of the 40-foot telescope, and as no excavation was possible, it was necessary to build a structure 36 feet high. Two towers were used after the plan adopted by Professor CAMPBELL at the Indian eclipse, and used also in Georgia. The inner tower was a mere skeleton of bamboo to support the lens. Around this was constructed another tower of bamboo, and covered with thatch to protect the lens-support from the wind. Upon this outer tower rested the frame of gas-pipe containing the canvas telescope-tube.



FORTY-FOOT CAMERA AND POLAR AXIS.

The ground was composed of sand and clay, saturated with water, and vibrations were easily communicated. The passage of a light cart along the street one hundred yards away caused such vibrations that sextant observations were impossible. It was feared that this unsteadiness of the ground would affect the images in the 40-foot telescope. In fact, the star-trails taken for focus did show irregularities, but as an examination of the Sun's image in transit and some experiments showed no vibration in the telescope, these irregularities could only be explained by atmospheric disturbances at night. It was noticed that the stars twinkled very markedly on all but a few nights.

Owing to the uncertainties of the climate, and the desirability of having shelter from the sun as well as from the rain, the roofs of the shelters for the intramercurial telescopes and the polar axis were hinged at the sides so that they could be opened or closed in a few seconds.

All of the smaller instruments, five in number, were mounted on one long polar axis, being driven by one clock. Although the exposures were of widely varying lengths, by using black cloths for exposing-caps and having all exposures, as far as possible, end at the same time, no difficulty whatever was experienced from jarring.

The tubes of the intramercurial planet telescopes, four in number, were made of sheet steel, five inches square at the objective end and increasing to the size of a 14 × 17 plate-holder. Each of the lenses was first mounted in a brass flange of good width. These were in turn secured by three sets of pushing and pulling screws to a brass casting screwed into the end of the steel tubes. This arrangement permitted of the final adjustment for focus and collimation with the same set of screws. The telescopes were mounted in two pairs, each pair consisting of two telescopes exactly parallel, thus permitting two simultaneous exposures of the same region of sky. The two pairs were so placed that their axes made an angle of 20° with each other, and were rigidly fastened together. This combination was then mounted on an auxiliary axis, which permitted the longer axes of the plates to be moved in the direction of the Sun's equator. As the 14 × 17 plates used covered a field of 5° 54′ by 7° 8′, two changes of position sufficed to cover a region 18° on either side of the Sun along his equator and nearly 6° in width. The most probable orbit of such a body would place it well within the region covered by such a series of photographs. The tubes and auxiliary axis were mounted in a large wooden box, and this in turn was mounted equatorially and driven by a clock operating at the end of a sector of ten feet radius. With the exception of the steel tubes, the mounting was constructed at the Lick Observatory by our skilled workmen. Though necessarily cumbersome, it performed admirably, being very rigid and coming to rest almost immediately after disturbance.

The performance of the single achromatic lenses * used for this work was very satisfactory. Good images were secured over a 14 × 17 plate with the exception of the corners, and even here the distortion was not serious.

All the instruments were mounted and practically in adjustment by May 12th. The intervening time was devoted to drilling the assistants, to checking the adjustments of the many instruments, and to arranging the final details.

A dark-room had been improvised, for night use only, in a small native bamboo house on the grounds. Preliminary experiments in photographic work had been made in the photographic department of the "Staatsspoorweg," which had been placed at our disposal by Mr. DELPRAT, Chief Executive of these government railways. The day temperatures generally ranged from 85° to 90° F., the air being almost saturated. The night temperatures were but little below 80°, with a heavy precipitation of dew. In continued rainy or cloudy weather the temperature fell to from 70° to 75° during the night and early morning. Photographic manipulations under such conditions were not easy, but with some changes in the formula, and by a liberal use of ice and alum, good results were secured with *fresh* plates. Plates exposed for any considerable time to the action of the atmosphere deteriorated rapidly, one of the most marked changes being a great loss of sensitiveness. It is not sufficient that the pasteboard boxes containing the plates shall be sealed; the only real protection is to have them hermetically sealed in metal boxes. The plates for eclipse work had been sent in two lots, one containing those needed for the focusing of the instruments, the

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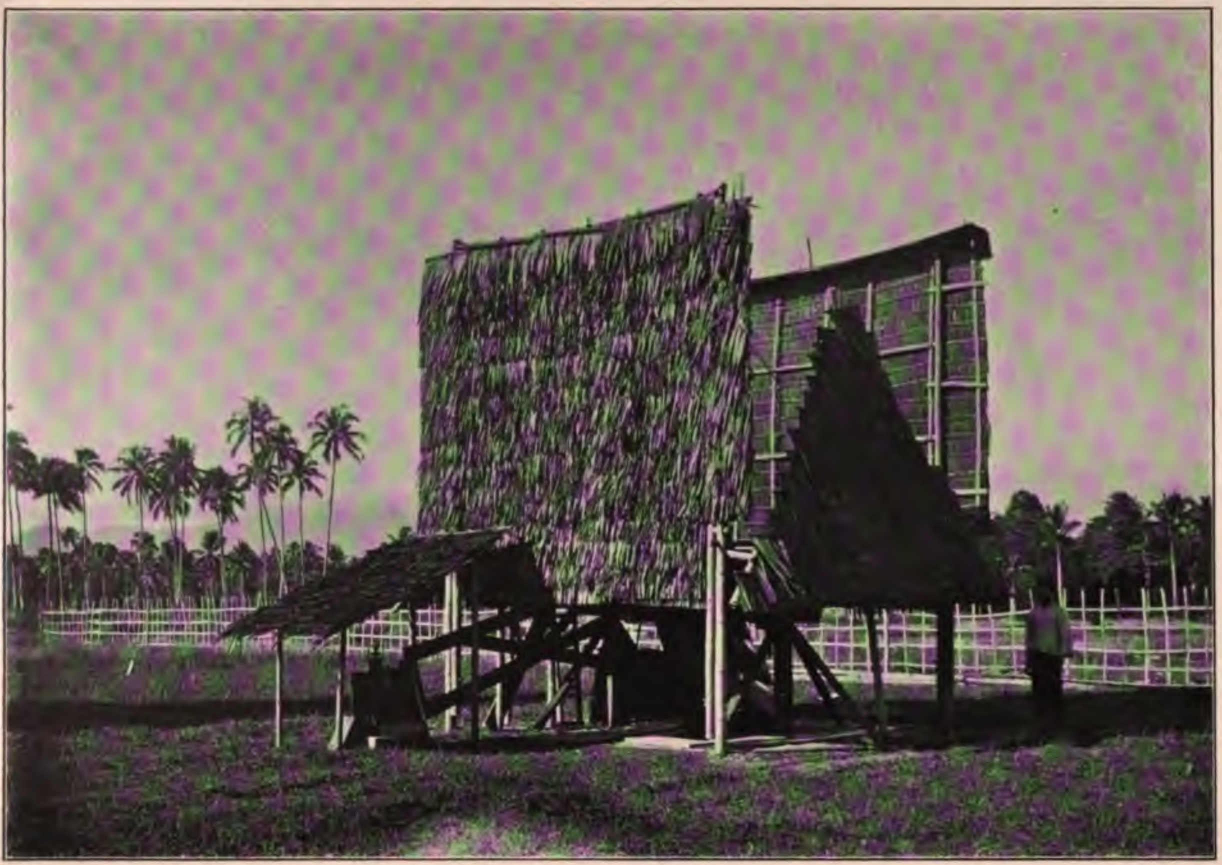
* These lenses were designed by Professor W. H. PICKERING, and used by him at the 1900 eclipse. Two of those used in Sumatra were kindly loaned by Professor E. C. PICKERING, Director of Harvard College Observatory. The other two were of the same design, made by ALVAN CLARK & SONS for the Lick Observatory, through the kindness of Professor PICKERING.



INTRAMERCURIAL TELESCOPES (SHELTER OPEN).

other lot for use on eclipse-day. Each lot was soldered up tightly in a tin box, that containing the plates for the eclipse not being opened until the night before, when all the holders were loaded. Plates which I carried along in my trunk, for viewing purposes, had so deteriorated, even before reaching Padang, as to be useless.

Offers of assistance in making the observations had been tendered liberally as soon as it was known that such help would be needed. Fifteen persons were invited to assist. Rehearsals of the programme to be carried out at the eclipse were begun four days before. In this way all gained familiarity with the necessary motions, and the programme was carried out with entire confidence. The observers and their stations were as follows:—

Time was counted at the chronometer and the necessary orders given (all in Dutch) by Mr. DELPRAT.

Forty-foot telescope: Messrs. R. H. CURTISS and F. BOUMAN.

Intramercurial telescopes: The exposures were made by Mr. NIEUWENHUYS. The plates were changed by Messrs. CLETON, GULDENAAR, D'HANENS, and PERRINE, the latter making the necessary changes of position of the telescopes.

Floyd telescope: The exposures were made by 1st Lieutenant P. L. DE GAAY FORTMAN, and the plates changed by 2d Lieutenant WARNSINCK.

Pierson (Dallmeyer) camera: The exposures were made by Mr. VON DER STRAETEN, and the plates changed by Mr. VON LEEUWEN BOONKAMP.

Radial slit spectrograph: This instrument was operated by Mrs. DE GAAY FORTMAN.

Tangential slit spectrograph: This spectrograph was operated by Mr. JUNIUS.

Polarigraph: The exposures were made by 2d Lieutenant SIEBURGH, and the plates changed by Mr. J. KEMPENS.

Shadow bands were observed by Mr. LAGERWEY.

The day before the eclipse had been one of clouds and rain, as was the day following. Eclipse-day dawned not altogether auspiciously, but with some promise. Light clouds covered the entire sky, but seemed to be growing thinner, and occasionally glimpses of blue sky could be seen. The Sun's disc was almost entirely free from clouds at first contact, although the rest of the sky was generally covered. The sky did not improve, however, as the eclipse progressed. At no time during totality was the sky about the Sun clear, light cirrus clouds and haze covering the entire sky, with the exception of a perfectly clear area near the northern horizon.

During the morning there had been some wind from the north, west, and south, but as the obscuration increased it began to die down. Canvas wind-screens had been placed about the polar axis and the intramercurial telescopes during the morning, but were not needed, as there was a perfect calm during totality. This dying-out of the wind I have noticed also at the two previous eclipses which I have observed.

The usual phenomena of light changes and cooling of the atmosphere were observed. No measures of light intensity were made, but a table of logarithms was placed where the light of the corona and surrounding sky shone fairly upon it and at mid-eclipse it was necessary to look closely to distinguish the figures. After the middle of totality the increase of light was quite marked, due partly, in all probability, to the increasing cloudiness. During the afternoon the sky overhead and to the west became entirely clear.

The entire programme was carried through successfully, although at that time there was scant hope of many results of value. No attempt was made to develop any plates in daytime, but during the following four nights the work was completed. It was an agreeable surprise to find that negatives of value had been secured with all the instruments.

Following is a list of the negatives secured, with the principal data relating to them, and a short description of the result on each:—

LIST OF NEGATIVES.

40-FOOT CAMERA.

No.	Size of Plate.	Kind of Plate.	Exposure.	REMARKS.
1	8 x 10	Carbutt B	½	Good.
2	14 x 17	Seed 27	1	Good. Detail off E. limb well shown.
3	14 x 17	Seed 27	2	Good. Detail off E. limb well shown.
4	14 x 17	Seed 27	4	Good. Corona to 15′.
5	14 x 17	Seed 27	16	Good. Corona to 15′.
6	18 x 22	Seed 27	40	Good. Corona to 20′.
7	18 x 22	Seed 27	150	Good. E. streamer to fully 1⅓ diameters.
8	14 x 17	Seed 27	4	Good. But little corona.
9	14 x 17	Seed 27	25	Good. About the same extension as No. 3.
10	14 x 17	Seed 27	8	Good. Much less than Nos. 3 and 4.
11	14 x 17	Seed 27	1	Good.
12	8 x 10	Carbutt B	½	First flashes of returning sunlight.

FLOYD 70-INCH CAMERA.

1	5 x 7	Seed 27	½	Good. Streamers to 10′.
2	5 x 7	Seed 27	2	Good. Eastern extension to one diameter.
3	5 x 7	Seed 27	8	Good.
4	5 x 7	Seed 27	4	Good. Streamers to 25′.
5	5 x 7	Carbutt B	60	Good. Streamers to over a diameter.
6	5 x 7	Seed 27	20	Good. Extensions only 15′.
7	5 x 7	Seed 27	2	Good. Extensions only 5′.
8	5 x 7	Seed 27	½	Good.

PIERSON (DALLMEYER).

1	8 x 10	Seed 27	½	Eastern streamers to one diameter.
2	8 x 10	Seed 27	2	Eastern streamers to one diameter.
3	8 x 10	Seed 27	8	Eastern streamers to one diameter.
4	8 x 10	Carbutt B	30	Over-exposed.
5	8 x 10	Seed 27	4	Slide not drawn.
6	8 x 10	Carbutt B	60	Over-exposed. Eastern streamer to 1¼ diameters.
7	8 x 10	Seed 27	20	Slide not drawn.
8	8 x 10	Seed 27	10	Corona to 20′.
9	8 x 10	Seed 27	2	Caught by returning sunlight.
10	8 x 10	Seed 27	½	Not exposed.

INTRAMERCURIAL.

No.	Size of Plate.	Kind of Plate.	Expo-sure.	REMARKS.
A 1	14 x 17	Seed 27	90^{s}	28 stars. Faintest = 8.8 visual magnitude.
B 1	14 x 17	Seed 27	90	
C 1	14 x 17	Seed 27	90	37 stars. Faintest = 8.6 visual magnitude.
D 1	14 x 17	Seed 27	90	
A 2	14 x 17	Seed 27	90	27 stars. Faintest = 8.8 visual magnitude.
B 2	14 x 17	Seed 27	90	
C 2	14 x 17	Seed 27	90	No star images.
D 2	14 x 17	Seed 27	90	
A 3	14 x 17	Seed 27	75	No star images. Inner corona and *Mercury* and *Venus* are distinct.
B 3	14 x 17	Seed 27	75	
C 3	14 x 17	Seed 27	75	No star images.
D 3	14 x 17	Seed 27	75	

SPECTROGRAPH I (SLIT TANGENTIAL).

No.	Size of Plate.	Kind of Plate.	Expo-sure.	REMARKS.
1	2⅛ x 3¼	Cramer Crown	320^{s}	Good.

SPECTROGRAPH II (SLIT RADIAL).

1	2⅛ x 3¼	Cramer Crown	320^{s}	Good.

POLARIGRAPH.

No.	Setting.	Size of Plate.	Kind of Plate.	Exposure.	REMARKS.
1	0°	3¼ x 4¼	Cramer Crown	1ˢ	Negative good.
2	0	3¼ x 4¼	Cramer Crown	10	Slide not drawn.
3	22½	3¼ x 4¼	Cramer Crown	1	Negative good.
4	22½	3¼ x 4¼	Cramer Crown	10	Negative good.
5	45	3¼ x 4¼	Cramer Crown	1	Negative good.
6	45	3¼ x 4¼	Cramer Crown	10	Negative good.
7	67½	3¼ x 4¼	Cramer Crown	1	Negative good.
8	67½	3¼ x 4¼	Cramer Crown	10	Negative good.
9	90	3¼ x 4¼	Cramer Crown	1	Negative good.
10	90	3¼ x 4¼	Cramer Crown	10	Negative good.

The negatives secured with the 40-foot telescope show the extreme inner corona and the prominences as well, probably, as if the sky had been clear. The two long exposures of 40 and 150 seconds, respectively, show detail in the middle corona, and the latter shows the streamers of the eastern equatorial extension to one and one-third diameters from the limb. Some of the detail at this distance is lost, however. A number of small prominences, exhibiting considerable detail, are shown on the east limb. One of these prominences, in position-angle 115°, is covered by a series of marked "hoods," or envelopes. There are other structures of this nature, but much less pronounced.

One of the most interesting features of the corona was an area in the northeastern quadrant where clouds of coronal matter were piled up as if by an explosion on the Sun's surface. That it is true coronal matter is indicated by the tangential spectrograph which had its slit across this region. The disturbed area appeared to have its origin in position-angle 65°, near a small compact prominence, and masses of matter are shown radiating from it in almost all directions. A long thread-like prominence to the south appears to emanate from this same region. The whole area resembles the condensations seen in photographs of the *Orion* and other irregular nebulæ. All the appearances point strongly to a direct connection with an eruption in some part of the Sun's surface, thus linking the corona closely with other solar phenomena, all requiring a single explanation. So far as I am aware, no such appearance as this in the corona proper has been observed at any previous eclipse.

The inner corona is well shown on the smaller-scale negatives obtained with the FLOYD telescope, but beyond one and one-quarter diameters the corona was so faint as to be lost in the clouds and haze. This is also the case with the negatives obtained with the PIERSON camera; in fact, with this instrument the long exposures recorded the images of the clouds. Owing to the inadequacy of the half-tone process to bring out fine details, illustrations of the corona are omitted for the present.

The clouds interfered most with the intramercurial planet search. The plates taken of three regions out of the six show 92 stars, the faintest being from 8.6 to 8.8 magnitude, but so far no star-images have been found on the plates of the other three regions. A careful preliminary examination of the plates was made at the station in Sumatra, but no suspicious object detected. A thorough search of all the plates will be made later, and it is hoped that some stars may be found on all of the plates, thus enabling some conclusion to be drawn as to the maximum brightness which any such body or bodies can have.

The earlier exposures with the polarigraph show the equatorial extensions of the corona to one diameter from the limb; toward the end of totality only about one quarter of a diameter is shown, owing to the increased cloudiness. A large percentage of polarization is indicated in the light of the corona beyond 10′ from the limb, and the later exposures point to a small percentage of polarization in the inner corona also. This is true of all position-angles, including the regions containing the polar streamers. The double-image prism used in this instrument separated the two images about 1¼ degrees. These were extremely convenient for comparison with each other, and the method of detecting polarization effects was practically a differential one.

The two spectrographs (as well as the polarigraph) were designed and prepared for use by Director CAMPBELL and Assistant Astronomer W. H. WRIGHT. The results obtained show both instruments to be very efficient for the purpose of recording dark lines in the spectrum of the corona. In a clear sky the spectrum of the inner corona would have been over-exposed.

Radial Slit Spectrograph.—The slit of this instrument was placed east and west across the Sun's center. The negative covers the region from λ 490 to λ 360 ±, the spectrum extending on either side of the Moon's disc to over a diameter. The image of a prominence on the east limb of the Sun covered the slit, producing very bright over-exposed *H* and *K* calcium lines, as well as the other characteristic prominence lines. On either side of the Moon's disc is a band of continuous spectrum about 8′ in width without any trace whatever of dark lines. Outside of this band at least 35 Fraunhofer lines can be counted between $H\beta$ and H, extending out to the limits of the spectrum. Beyond $H\beta$ and H, in either direction, there is but little trace of the spectrum of the outer corona. A longer exposure would doubtless have shown all the Fraunhofer lines observable with the slit-width and dispersion used. Bright H and K lines of marked strength extend entirely across the Moon's disc, and to a distance of 40′ east of the Sun's limb, but show only feebly on the west side of the Sun. They are symmetrical with reference to the image of a prominence on the east limb, indicating a diffusion in our atmosphere of calcium radiations from this and other neighboring prominences. Comparisons with a sky spectrogram secured with the same instrument show that the coronal and sky spectra are sensibly the same in the blue and violet regions.

Tangential Slit Spectrograph.—The slit was placed north and south across the corona about 2′ east of the Sun's east limb. The negative shows practically the same range of spectrum as the preceding one, with a width of rather over a solar diameter.

The H and K lines are bright and quite strong, the latter having the greater intensity. No doubt these are due to calcium radiations diffused in our atmosphere. No other bright lines are to be seen. Although the continuous spectrum is strong, none of the details are obliterated. Several stronger bands extend longitudinally through the spectrum, which are due in all probability to the brighter condensations in the corona proper. Many Fraunhofer lines are visible, especially between $H\gamma$ and K, and can be traced across the full width of the spectrum. They are less distinct where they cross the dark belts mentioned above. The disturbed area of the corona, already referred to, fell across the slit of this instrument. This spectrogram was also compared with a sky spectrogram, as in the previous case, and the same agreement of the lines was noted.

A consideration of all the facts shows that the clouds have not affected these results nor their interpretation.

Professor CAMPBELL has examined these spectrograms and confirms the above results.

It should be noted that the spectroscopic observations made at the India eclipse of 1898 by Professor CAMPBELL also showed no trace of dark lines in the inner corona. These spectrograms extended only to a distance of 2′.5 from the limb, being obtained with high dispersion.

The preceding spectroscopic and polariscopic observations seem to point to a very definite explanation of the general constitution of the Sun's corona. Both methods of investigation show that the light of the outer corona is in great measure reflected sunlight, whereas the spectrograph shows the light from the inner corona to emanate principally from incandescent matter. These facts, taken in connection with the varying appearance of the corona, suggest as the most probable explanation that very finely divided matter is ejected from the surface of the Sun with great velocity, giving rise to the streamers and extensions observed. This matter may or may not be solid when it first leaves the Sun, but observation indicates that it is incandescent, and probably largely solid, when it first becomes visible above the layer of chromosphere. While in a state of incandescence its inherent light would in all probability be so great as to mask the light which must be reflected from the solar surface; but a point would be reached in its outward journey where it would become cool enough for the reflected light to become observable. Actual radial motion has not been observed in true coronal matter, but appearances point far more strongly to great movement than to a state of comparative rest.

The well-known bright lines observed on many occasions in the corona indicate, also, an irregular but comparatively thin gaseous envelope about the Sun. The quantity of light contained in the bright-line spectrum, however, is very small in comparison with that composing the continuous spectrum; and it is probable that the gaseous envelope does not appreciably affect the ordinary photographs of the corona.

The explanation suggested above, deduced through a different train of reasoning, from an entirely distinct set of facts, is in accord with the conclusion reached by Professor SCHAEBERLE from a study of the forms of the coronal streamers shown in his large scale photographs of the 1893 eclipse, that these streamers are composed of matter ejected from the Sun with great velocity.

The sky was unfavorable for Shadow-Band observations. Mr. LAGERWEY, however, detected faint bands at the beginning of the eclipse. These bands had wavy outlines at first, becoming almost straight toward the end of their apparition. The direction of the wave front was north 60° east and south 60° west, the waves moving in a direction at right angles to the wave front.

TIMES OF CONTACTS.

The first three contacts were observed by me, as follows:—

	h.	m.	s.	
I	22	45	30.9	mean time of station.
II	0	18	52.3	
III	0	25	1.3 ± 1^s	

Observed duration of totality, $6^m 9^s.0$.

The following are the times of the contacts for the station, computed from the data given in the American Ephemeris:—

	d.	h.	m.	s.	
Beginning of eclipse,	May 17	22	45	16.1	mean time of station.
Beginning of totality,	May 18	0	18	49.9	
End of totality, . .	May 18	0	24	56.8	
End of eclipse, . .	May 18	1	57	25.5	

Computed duration of totality, $6^m 6^s.9$.

Contact I was observed with the sextant, and is probably 2^s or 3^s later than geometrical contact. Contacts II and III were observed without optical aid. Contacts I and II were timed directly from the chronometer; contact III by means of the counts of the timekeeper, and is subject to a possible uncertainty of a second. As soon as possible after totality the counts were compared directly with the chronometer. The corrections to the chronometer were determined from sextant observations of the Sun.

The time observation secured after the eclipse indicated a considerable change of rate of the chronometer subsequent to the observation of the same morning. About ten minutes before the beginning of totality the chronometer was removed from the shelter, where it had remained undisturbed on a pier, in order to permit the timekeeper to have a view of the eclipse, and replaced in its original position shortly after totality. In determining the chronometer corrections at the time of the contacts it has been assumed that the change of rate occurred with the change of position of the chronometer.

THE GREAT SOUTHERN COMET.

On May 4th a telegram was received from Professor SKINNER announcing that a brilliant comet had been observed by Mr. DINWIDDIE at Solok, in the western sky, just after sunset of the previous evening. The evening of May 4th was cloudy at Padang, but the evening of May 5th was clear, and the comet was seen low in the west against a very bright sky. Sextant observations were secured of its position, using the nearest available stars. As the sky darkened it became a very conspicuous object. It had a brilliant nucleus, and a tail 6° to 8° in length. The Pierson camera was mounted on the following day and directed to the place of the comet. Owing to the brightness of the sky and to the lack of means for following the comet, only short exposures were attempted. Four negatives were secured on May 6th, as follows:—

	Duration of exposure.	Length of tail.
No. 2_2	1^m	3°
4_2	3	3½
1_4	7	4
1	$0^m\ 30^s$	

The last plate contained no image, owing to the haze and proximity of the comet to the horizon.

The principal tail is composed of two slightly curved and nearly parallel streamers. The second and third negatives show a very faint streamer to the south, making an angle of 35° with the axis of the principal tail.

Clouds near the western horizon prevented any further observations or photographs, although the instruments were left in readiness until it became necessary to adjust them for the eclipse.

Mr. Ralph H. Curtiss, formerly assistant in the Students' Observatory, University of California, was appointed assistant in the Lick Observatory from February 15th, and accompanied the expedition, helping throughout in the work of preparing the station and in the observations.

A most cordial welcome was extended to eclipse observers by the officials and citizens of Padang, and I am largely indebted to them for the results secured. Especial thanks are due to His Excellency, Governor Joekes for introductions to heads of departments and for his interest in the welfare and safety of the expedition at all times; to Kolonel H. F. C. van Bijlevelt, commander of the army, who detailed a number of his officers to take part in the observations; to Major Muller, of the general staff, N. I. Army, for advice as to the meteorological conditions and the choice of a station, as well as for many practical suggestions; to Assistant Resident Hartogh Heiss, head of the police department of Padang, who not only made arrangements for the location for the station and obtained watchmen, but in his official capacity had the safety of the camp as his immediate care. On the day of the eclipse a body of twenty special policemen, with an equal number of employees from the railway, formed a cordon about the camp.

Mr. TH. F. A. DELPRAT, as chief executive of the railways, not only furnished free transportation for observers and apparatus over the railroads, but placed a fully equipped photographic dark-room and the facilities of the very extensive shops and stores at our disposal, detailed skilled workmen for specially important work, and at all times was ready to give advice and cordial help.

Mr. F. BOUMAN, chief of the construction department of the railways, with a wide acquaintance of the natives, practically superintended the construction of all the shelters and buildings required. We were thus relieved of many of the trials and extortions incident to dealings with the Malays by foreigners.

Mr. C. G. VETH, United States Consul at Padang, extended many courtesies to the eclipse observers, and was ready at all times to aid them. After the eclipse and just before the departure of the U. S. S. "General Alava," with the U. S. Government party of astronomers aboard, a banquet was given by Consul VETH in the ship's honor, to which all the astronomers were invited. It was a great surprise to hear the English language so generally spoken. A most enjoyable time and one long to be remembered was the result.

Social courtesies were freely extended by the residents of Padang, and served to enliven our busy sojourn there.

Those who took part in the work of observation were: Heer TH. F. A. DELPRAT, 1st Leutenant der genie P. L. DE GAAY FORTMAN, 2d Leutenant der Infanterie W. H. WARNSINCK, 2d Leutenant der Infanterie E. SIEBURGH, Mevrouw DE GAAY FORTMAN, Heer J. KEMPENS, Heer F. BOUMAN, Heer VAN LEEUWEN BOONKAMP, Heer VON DER STRAETEN, Heer JUNIUS, Heer CLETON, Heer NIEUWENHUYS, Heer GULDENAAR, Heer D'HANENS, Heer LAGERWEY.

The greatest enthusiasm was manifested by all in the preliminary rehearsals as well as in the observations on eclipse day.

Favors were shown to the expedition in all possible ways, from Mt. Hamilton to Padang, every one being not only willing but anxious to aid. Among these especial mention should be made of Mr. ROBERT BRUCE, of the firm of Balfour, Guthrie &

Co., of San Francisco; the Toyo Kisen Kaisha; the Occidental and Oriental Steamship Company; the Pacific Mail Steamship Company; the officers of the S. S. "Nippon Maru"; Mr. AUBREY FAIR, of Hong Kong; Mr. A. I. Ross and Mr. T. SCOTT of the firm of GUTHRIE & Co., Singapore; the agents and officers of the "Koninklijke Paketvaart-Maatschappij" and "Stoomvaart Maatschappij Nederland"; the representatives of the firm of J. DAENDELS & Co., in Singapore, Batavia, and Padang; the officers of the Hong Kong and Shanghai Bank, in San Francisco and Batavia, and the Java Bank, in Padang.

The natives were much aroused at the advent of so many astronomers, and the preparations for an event in which they had at first no faith whatever. Some of the keenest of their religious leaders, however, saw an opportunity, and shortly before the eclipse began to prophesy and to take much credit to themselves. The advent of the comet a fortnight before the eclipse and an epidemic about the same time in the native Kampong, from which many died, excited the more superstitious ones, and a rumor was brought to me that our camp was to be demolished. Whether we were in any particular danger or not will probably never be known, but there was anxiety in the police department until all was over. Our stay ended without an interruption and without any loss or damage to the instruments.

At the suggestion of Professor TODD, the various telegraph companies offered to transmit a message from Mauritius to the observers at Padang, giving them an hour or more in advance, the benefit of observations at the former point. A letter was sent to Padang, addressed to eclipse observers, by General Manager TAYLOR of the Eastern Extension Australasia and China Telegraph Company, Limited, at Singapore, notifying them of the arrangements made by the different lines for the transmission of this message. This letter was delivered by the postal authorities to me, and I at once notified all observers in Sumatra, within my knowledge, of its contents. Arrangements were made with the telegraph office in Padang for the prompt distribution of this message, which, however, failed to arrive.

After the eclipse was over, and the instruments all packed for shipment, a few days were spent in the interior of this very interesting but little-known island, visiting the peculiar native markets, climbing one of the active volcanoes, and seeing the Malays at home.

The lowlands of these tropical islands are hot, humid, and uncomfortable, but the higher lands have a most delightful temperature. At altitudes of 3,000 to 4,000 feet the temperature was that of a perfect early summer day of the temperate zones, very warm at midday, if clear, but pleasant at night,— cool enough for a light bed-cover, but without any chilling winds. The humidity at all altitudes is very near the saturation point, which, together with the warmth, causes a most luxuriant vegetation everywhere, a dense, impenetrable jungle where not kept down by constant work. Even the volcanic peaks which have been in eruption within a generation are again clothed with dense forests, covering all the scars. The rugged mountains, the towering volcanoes, some of them still active, the rice-paddies, the picturesque habitations of the natives, and the natives themselves, offer sights and adventures of surpassing interest, for this is indeed a world *contra* to all temperate climes.

Both going and returning we passed Krakatoa, in the Straits of Sunda, and it was not without a thrill that I looked upon that relic of a convulsion of nature which has perhaps no equal in history. Its appearance is proof enough of the tales of that outburst in 1883, when a superb volcanic cone half a mile in height was split asunder and one half lost in the sea; when all the contiguous islands and the near-by coasts of Java and Sumatra were devastated, their inhabitants and wealth utterly destroyed, and even the very face of nature changed; when ships were carried miles inland by the tidal wave over hills as high as their masts,— a convulsion which was thought to be the "crack of doom" by millions, and which was in reality such to tens of thousands. In April this giant was without any sign of life, but early in June smoke in considerable volumes could be seen rising from the almost perpendicular north face, the scar of the outburst of eighteen years ago.

It was a great pleasure to renew a number of acquaintances in Sumatra, and to meet for the first time many prominent astronomers from all parts of the world.

MT. HAMILTON, CALIFORNIA, 1901, November 11.

THE CAMP AT FORT DE KOCK.

THE U. S. NAVAL OBSERVATORY ECLIPSE EXPEDITION TO SUMATRA.

By Heber D. Curtis.

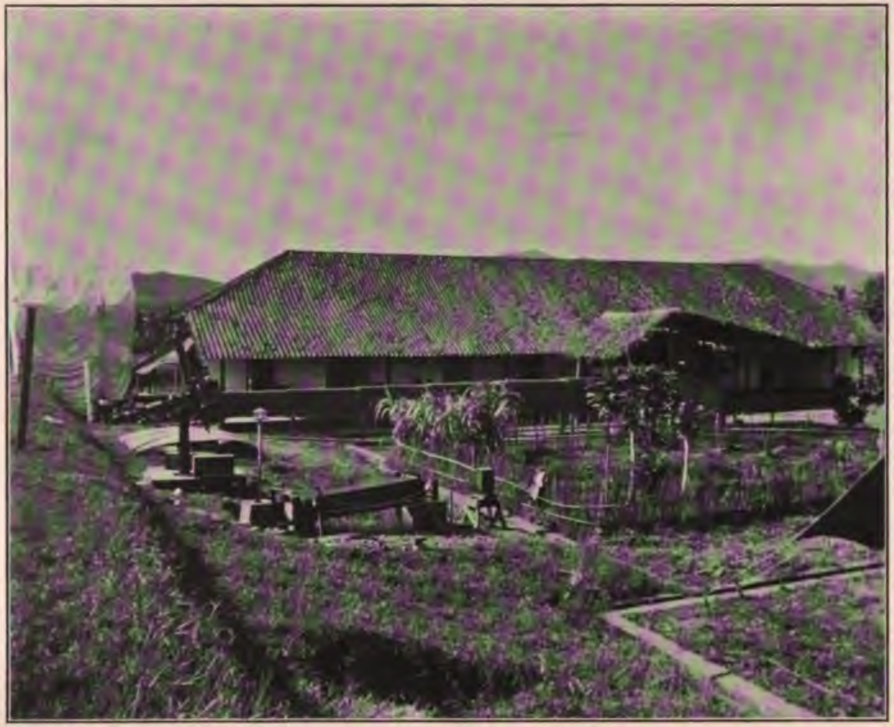
In pursuance of the liberal and progressive policy which provided for the observation of the eclipse of May, 1900, and for numerous extensive expeditions in the past, the Government late in 1900 appropriated the sum of $10,000 for an expedition to observe the total eclipse of May 18, 1901, in Sumatra. Owing to the exceedingly limited time, some of the special apparatus was necessarily constructed in great haste; but everything was ready by February 7th, a date which would give none too much time for the long journey and the equipment of the camps.

The Naval Observatory party proper numbered eleven members, namely: Professor A. N. Skinner, U. S N., Director; Professor W. S. Eichelberger, U. S. N., Assistant Astronomer, F. B. Littell, Mr. George Peters, Mr. L. E. Jewell, and Mr. W. W. Dinwiddie, of the Naval Observatory; Professor E. E. Barnard, of Yerkes Observatory; Dr. S. A. Mitchell, of Columbia University; and Dr. W. J. Humphreys and the writer, from the University of Virginia. Associated with the Naval Observatory on the trip was the Smithsonian party—Mr. C G. Abbott, and his assistant, Mr. Paul A. Draper, of Washington. The distance to be traveled was nearly 14,000 miles by the route selected, the cost of which would have eaten very heavily into the available appropriations had not the party, through the courtesy of the Secretary of War and the Secretary of the Navy, been carried between San Francisco and Manila on a Government transport, and from Manila to Sumatra on the U. S. gunboat "General Alava."

San Francisco was left on February 16th, on the U. S. A. T. "Sheridan." The month-long sea-trip to Manila was pleasantly broken by a few days at Honolulu. Here we enjoyed the generous hospitality of the Hawaiian Philosophical Association. Many of our most pleasant memories of this garden-spot of the Pacific are due to their thoughtfulness and courtesy. The charms of the sail southward through the tropics will not soon be forgotten by any of the party. Some industrious astronomers busied themselves with computations. Frequent conferences of all the members were held to deliberate on the methods to be followed and results hoped for in Sumatra. Occasionally the land itself came up for discussion, and it was on one of these occasions that the reading from various books of travel of highly colored passages with regard to the serpents of the East Indies brought it about that these conferences were henceforth known to the laity as meetings of the "Snake Club." Thanks to several energetic young officers, other diversions were not wanting; two minstrel shows, several lectures and addresses, a dance, a tug-of-war and two spirited boxing tournaments among the soldiers varied the monotony, and all short-comings were condoned in the Mid-Pacific. Consul WILLIAMS, formerly stationed at Manila, but now at Singapore, was one of the passengers on the "Sheridan," and it was through his kindness that after reaching Manila we were taken about the bay in a Government launch over the track that DEWEY followed, while the Consul himself, who was on the bridge with DEWEY, told us many interesting details of the battle and pointed out the forlorn wrecks of the Spanish war-vessels.

The distance from Manila to Padang, Sumatra, is about 2,200 miles, and this portion of the trip occupied us ten days, which passed quickly enough in the warm and many-hued waters of the China and Java seas, past interminable island-continents that the geographies of our younger days represented as apparently of equal area to the Bahamas. Both going and returning through the Straits of Sunda, we passed within less than a mile of Krakatoa, where Verlaten and Lange islands still show the former extent of Krakatoa before its tremendous eruption.

On April 1st we enjoyed the astronomical novelty of a vertical Sun. On this day, at apparent noon, the Sun was only four minutes of arc from our zenith. I took a sextant and, bringing the Sun into coincidence with the horizon, swept the entire circle of the horizon without having Sun and horizon leave the field of the sextant. On the "Alava," also, we went through the time-honored ceremony of "crossing the line," an interesting and laughable rite of sailing-ship days now not frequently seen. Father and Mother Neptune and their motley crew "came aboard" to hold their royal equatorial court. A large tank of salt water was improvised from a canvas sea-anchor. All tyros on board must needs be presented, and several astronomers were among them. Neptune's doctor administered a soap pill; the ace was lathered with a vile mixture of red-lead and molasses;



THE 61½-FOOT TELESCOPE, WITH INTRAMERCURIAL CAMERA SHELTER IN BACKGROUND, SOLOK.

then followed a none too gentle shave with a two-foot wooden razor in the hands of Neptune's barber, a sudden twist by the stalwart jackies, and the victim made room for the next culprit by a beautiful back somersault into the salt-water tank.

It was nearly two months after leaving Washington that we finally cast anchor in the beautiful land-locked harbor of Emmahaven. The meteorological reports of the Dutch Government had been carefully studied, and Solok on the Padang plateau had already been selected as the chief station. After a few days spent in reconnoitering, the members were soon at the respective stations. Three stations were selected, well separated from each other and from the camps of other parties — Solok, Sawah Loento, and Fort de Kock. The first two are over one thousand and the last named nearly three thousand feet above sea-level, and are situated from fifty to eighty miles from Padang.

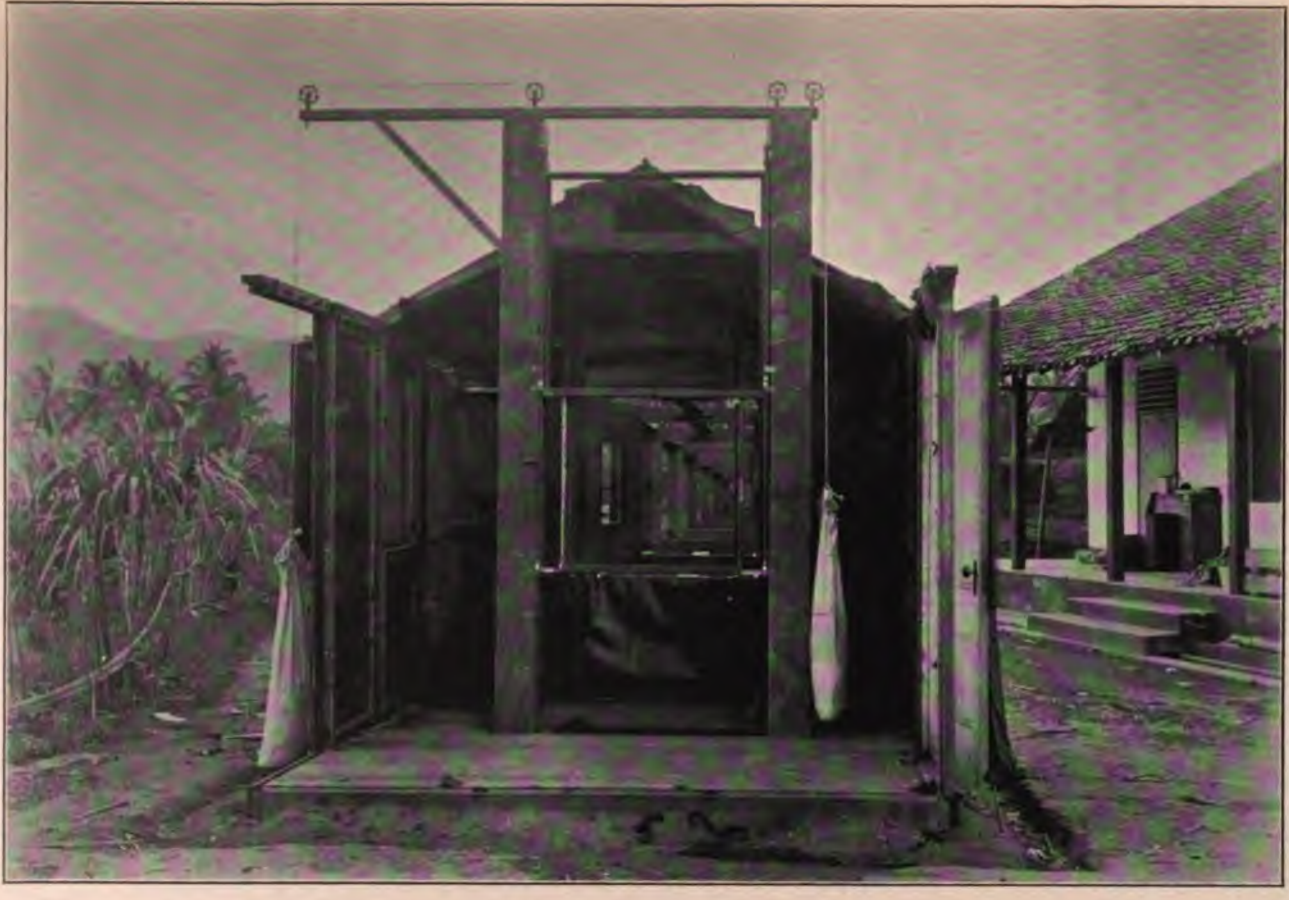
Solok was thirty-one miles from the central line; it was impracticable to go nearer the middle of the eclipse track, except on the coast, and stations were already chosen there by other parties. Alahan Pandjang, very near the central line, had been considered. It lies some thirty-five miles south of Solok, and is reached by an excellent road; but as our heavy equipment would have had to be transported there on the backs of coolies, it was decided that the increased advantages of this site would not warrant the time and the expense necessary to overcome the difficulties of placing a camp at this spot.

Fort de Kock, the northern station, was about seven miles south of the northern edge of the shadow, and the duration of the total phase at this point $2^m 40^s$. Here it was purposed to devote efforts particularly to the spectrum of the flash and inner corona and photographs of the inner corona with special reference to the polar streamers. Professor W. S. EICHELBERGER was in charge of this camp. Dr. W. J. HUMPHREYS here employed the 21½-foot concave grating belonging to the University of Virginia, while Mr. PETERS had charge of the forty-foot camera,— the lens, the property of the Naval Observatory, being the one used by Professor STONE in May, 1900, at Winsboro, N. C. In this instrument no plate-holders were used, but the plates placed and held against an adjustable frame placed at the focus.

Sawah Loento is a little town surrounded by mountains on all sides and is near the great government coal-mines. It is the southern terminus of the Sumatra Government Railroad, which was built primarily to bring the coal from these mines to the sea-coast. The coal is of very fair quality, and the mines are remarkable chiefly for the thickness of the deposits, one seam, I believe, having the unparalleled thickness of forty-two feet. The labor is entirely convict. The Dutch Government, with characteristic thrift, transports its Sumatra offenders to Java and the Javanese to Sumatra. These races hate one another so cordially that an escape of a convict is out of the question, and very little guarding is necessary. The curious little railroad was made to fit the country, not the country leveled and cut to make an easy road, and through the mountains engines of a composite type are used, on which supplementary gearing can be thrown into action on a heavy rack laid between the rails; the grades thus overcome are in several spots nearly 600 feet to the mile. It is an exceedingly picturesque road through the tropical growth of the mountains and the terraced rice-fields of the foot-hills; especially noteworthy is the beautiful Aneikloof gorge a few miles below the town of Padang Pandjang. The Naval Observatory station at Sawah Loento was located on the hillside about a mile from town and a few hundred feet above it, quite near the camp of the Massachusetts Institute of Technology. Dr. MITCHELL here had a large-grating spectroscope and a six-inch lens of 104 inches focal length. He was assisted by Mr. RENÉ GRANGER, of Cartersville, Ga., who came independently via London to give his services to the party.

The main station was located at the village of Solok (Long., 6^h 42^m 36^s E.; Lat., 0° 47′ 17″ S.). Here Professor SKINNER was particularly fortunate in securing for the eclipse camp a small fort which had been abandoned for about two years. It was about two hundred feet square and was surrounded by a wall, moat, and a *cheveau-de-frise* of wire tangle which effectually isolated the camp from the over-curious native. Along one side ran the large cement-floored barracks, which formed an excellent storehouse, and served also as sleeping quarters for four of the party, Hotel Talang, with a maximum capacity of six guests, being swamped by the influx of visitors. In one end of these barracks were located Mr. ABBOTT'S constant temperature room for the bolometric work. The fort was well drained, and the former powder magazine made an excellent dark-room.

At this station were located Professor BARNARD, with the



REAR VIEW CF THE 61½-FOOT CAMERA, SHOWING MECHANISM.

61½-foot camera; Mr. LITTELL, with a flat-grating spectrograph, and Mr. L. E. JEWELL, with a concave grating; Mr. DINWIDDIE, with a prismatic camera fitted with a large prism, loaned by the Smithsonian Institution; Dr. GILBERT, with a spectropolarigraph, loaned by Professor WOODS, of the University of Wisconsin; and the writer, in charge of a 7¾-inch lens of 114 inches focal length and a pair of large cameras mounted on a six inch equatorial.

Professor BARNARD'S instrument received its light from a large coelostat provided with electrical control. The details of the tube and house are seen in the photographs. The electrical control worked perfectly. His method of exposing the plates may be seen in the cut of the interior of the photographic house. Two pillars of 8×8 timber were set firmly five feet in the ground; between these ran smoothly a counterpoised framework with suitable guides and stops. The upper compartment of the framework held a 40×40 plate-holder; the lower held 30×30. The larger holder remained in the sliding frame during the eclipse. The various 30×30 holders could be very quickly slipped in and removed after exposure. At the proper time the frame was pulled down so as to bring the image of the Sun in the center of the 40×40 plate, and after the exposure the frame was pushed up for the remaining exposures on the 30×30 plates. The 40×40 plate, the largest ever exposed for astronomical purposes, received an exposure of two minutes and a half. To prevent excessive over-exposure of the inner coronal regions, a screen of about the size of the Moon's image (nearly eight inches) was fastened to a long wire handle. The edges of this screen were covered with absorbent-cotton so as to be fluffy and ill-defined, and in use it was kept constantly in motion over the image of the Sun on the plate. All plates were backed, and those for the longer exposure on the smaller cameras and all those on the 104-inch and 114-inch telescopes, which were provided with visual lenses, were slow orthochromatic.

Mr. ABBOTT'S intramercurial camera had numerous points of interest. A strong equatorial mounting carried four large cone-shaped tubes built up of small wooden rods so as to combine great rigidity with lightness. These were covered with light-proof rubber cloth. The four lenses were compound, of four inches aperture and eleven feet focal length. The same clock ran a large mirror on the telescope pier which threw the beam of light into the bolometric room, some ten feet distant. Each tube carried two 24×30 plates so arranged on hinged frames that one plate lay flat against the side of the tube while the other was in position. At the slipping of a catch the exposed plate was drawn up against the side of the tube by springs, and the second as quickly rotated into position, the entire operation occupying only a few seconds. The large shelter, covered within with black cloth, was a dark-room and camera combined, the exposures being made by a sliding curtain at the top.

Cut films were used on the various spectrographic plate-holders, bent to the proper radius against curved guides. The sliding plate-holders were equipped with suitable stops, so that successive films could be exposed with very little time lost in shifting.

Efficient assistance on the day of the eclipse was given by Mr. IRVING, a colporteur of the English Bible Society, who acted as our interpreter, and by Surgeon ODELL, Lieutenant CHASE, and nine sailors from the "General Alava." Accustomed to the discipline of a man-of-war, these intelligent and capable sailors took naturally to the drills preparatory to the eclipse and went through their programmes without a hitch. A break-circuit chronometer sent signals to a telegraphic sounder at each instrument; the minutes were struck on a locomotive-bell.

Only those who have been through similar experiences can realize the labor involved in setting up and adjusting the instruments of a large eclipse camp. Though we were agreeably disappointed to find in this portion of Sumatra a well-ordered colony, and not a tropical wild, there were many needs and emergencies in which we felt the limitations of the island very keenly. We found Dutch of comparatively little value, and learned Malay perforce, for the Dutch Government forbids the use of Dutch by the natives. Labor was cheap,—twenty to forty cents gold a day,—but of poor quality; for all work requiring more skill Chinese are employed. Watchmen were furnished us free by the Government,—two wizened hill-natives, who regularly slept through the night on our barrack porch. In this and other ways we came in contact with the "Heerendienst," or forced-labor system, of the Dutch Government, a much-criticised policy, but one which has certainly produced wonderful results in Java. Our greatest difficulty lay in the climate itself; for it was soon evident that our chances of a fair day were very poor. In such a land as Sumatra, where there are only two seasons,—a wet, and a wetter,— the difficulty lay in finding even gaps in the clouds for the necessary astronomical adjustments.

In all our difficulties, however, we found the Dutch officials ever helpful, kind, and obliging. It would be impossible to say too much of the kindness of the Colonial Government in this particular, its foresight in preparing for us in every way. Free transportation for all freight and baggage and an unlimited pass for all visiting astronomers were not the least of its favors. With every official, from Governor YOEKES to the humblest railroad employee, "Zoneklips" was an "open sesame."

Though it was foreseen that the chances were very poor, a few very good days in May had raised the hopes of all, and it would be useless to try to describe the feelings of the party at Solok as the 18th of May dawned with the sky covered with clouds. To the north a beautifully clear patch could be seen over Lake Sinkarak, too slowly approaching, for it reached us three hours after the eclipse. From computations made by Mr. LITTELL and the writer, the more important data for the eclipse at Solok were—

Contacts.	Solok Mean Time.
I.	May 17, $22^h\ 47^m\ 31^s.8$
II.	May 18, $0^h\ 21^m\ 20^s.8$
III.	May 18, $0^h\ 27^m\ 12^s.7$
IV.	May 18, $1^h\ 59^m\ 36^s.2$

Duration of total phase $5^m\ 51^s.9$.

Observations by Professor SKINNER with a three-inch telescope and of the first and fourth contacts with the six-inch by the writer agree in placing the observed eclipse about 12^s ahead of the computed time.

At the time of second contact the sky was covered with a layer of clouds not quite thick enough to conceal *Mercury* or *Venus* but sufficient to cut off all sight of the corona except a very narrow rim around the edge of the Moon, and it was with a feeling of the futility of further efforts that we went through our respective programmes. From about the third minute of totality, even the narrow rim of light disappeared; it was impossible to locate the eclipsed Sun visually, and plates taken at this time show nothing but fog. An interesting feature noticed by other observers under similar conditions was the quantity of light still present, reflected by the clouds from the illuminated land beyond the eclipse track. The lanterns which had been provided for a "dark" eclipse were entirely superfluous. It seemed to me personally to be lighter at Solok in mid-totality that at Thomaston in 1900 ten or twenty seconds before second contact,—this though the eclipse path was nearly one hundred and fifty miles wide and we were thirty-one miles from the central line. At Fort de Kock, on the other hand, where the sky was perfectly clear, lanterns were needed, although they were only seven miles from the edge of the shadow.

Thus even the hope of a veteran astronomer that we should be favored either with a clear sky or a pouring rain was not realized, for surely the most mournful part of an unsuccessful eclipse is the hopeless development of the great plates from which so much had been expected. Practically nothing of value was secured at Solok, equipped with what was perhaps the most powerful and representative array of instruments ever set up in a single camp. The prismatic camera secured a good film of the first flash, and some of the faster plates secured the rim of the inner corona, but hazy from drifting clouds. Mr. ABBOTT attempted no bolometric work; while quite a number of stars were made out on his plates taken in the first half of the eclipse with the intramercurial camera, it seems that the conditions prevailing at every camp where instruments of this sort were in operation leaves this problem still open, a question which it was hoped might be definitely settled at this unusually long eclipse.

Better results were secured at Sawah Loento by Dr. MITCHELL and Mr. GRANGER. The clouds here were much lighter, and the spectroscopic results in particular promise well.

Fort de Kock was the only camp on the island blessed with absolutely clear weather, and several excellent photographs were secured by Mr. PETERS and Dr. HUMPHREYS. All other camps had light clouds, though in many cases insufficient to ruin the spectroscopic and polariscopic results.

It took far less time to pull down than to fit up the camp, and several days were then very pleasantly spent in seeing the sights of this exceedingly interesting but little-visited corner of the globe. Several of the party ascended the active volcano Merapi, nine thousand feet high and only a few miles from Fort de Kock; the jungle climb to Pajo, near Solok, affords what is said to be one of the most beautiful views in the East Indies, and to all of us, the native, his customs and peculiarities, his picturesque, beautifully carved and decorated houses, formed a fascinating subject for observation and photography. This central portion of Sumatra is thought to have been the original home of the Malay race. It is now well under Dutch control, and is covered with almost perfect roads, many of them dating from the English occupation of the island, roads which can not be paralleled in any State in the Union. At the north of the island, at Atjeh, the brave and capable Malays have been at continuous warfare with either the English or the Dutch for nearly one hundred years, and only thirty miles inland from Solok one finds the boundaries of the independent native states, to many of which no white man is admitted.

Aside from two weeks spent at Manila, our long trip home was without special interest, and we were very glad to disembark from the U. S. A. T. "Indiana" after nearly six months absence.

The camps of the various expeditions were quite well separated, from the Dutch and English on the coast near Painan to our own camp at Sawah Loento, while on the eastern coast of Sumatra Professor TODD occupied the island of Singkep. Over all this portion of the path the rule was cloudy weather, and it is to be regretted that in such an important eclipse as this one, especially in view of the tropical and exceedingly uncertain weather, the stations were not scattered even more widely. The Dutch were quite anxious that some nation should send its expedition to Borneo or Celebes. The conditions here would have been somewhat more difficult, but in no sense dangerous, and a station or two somewhere in this neglected portion of the shadow-path might have saved the day.

LEANDER MCCORMICK OBSERVATORY, Charlottesville, Va.

THE *LEONIDS*—GRAND DISPLAY OF METEORS AT LOWE OBSERVATORY.

BY EDGAR L. LARKIN.

The usual stream of *Leonids* was observed here from midnight until dawn November 15, 1901. The first meteor was seen at 11^h 53^m P.M. on the 14th, before the radiant rose above the peaks standing sentinel 1,800 feet east of the observatory. The altitude of the observatory is 3,420 feet, and the line of peaks from north to south varies in height above the building from 80 feet in the southeast to 1,340 feet in the northeast; so ***Regulus*** did did not rise until 0^h 49^m November 15th. When the radiant came up alongside of a cliff the rate of meteors was one per minute.

TABLE OF TIMES AND METEORS, NOVEMBER 15, 1901.

Times (P. S. T.)		Number of Meteors.
From 0^h 00^m to 1^h 00^m		32
1 00 1 54	Cloud before *Leo*	27
1 54 2 53		27
2 43 3		19
3 01 4		173
4 5		297
5 5 40		109
	Total,	657

Half, or probably slightly less, had trails of all degrees of brilliancy, and in length from 2° to 15°. Four fifths, by estimate, were white, a small number greenish-blue, a few tinged with red, while two were full red. Those leaving streamers were at high speed and seemingly at great altitude; others seemed near the Earth, the small ones not being visible more than half a second.

TABLE OF DIRECTIONS.

From ε *Hydræ*	toward α *Columbæ*.
Præsepe	ε *Hydræ*.
ε *Hydræ*	*30 Monocerotis*.
Præsepe	γ *Leonis*.
Præsepe	*Procyon*.
Regulus	*Ursa Majoris*.
ε *Hydræ*	*Regulus*.
Procyon	*Sirius*.
Castor	*Betelguese*.
Sirius	Ocean.
Regulus	*Naos*.
Procyon	*Sirius*.
30 Monocerotis	*Canopus*.
30 Monocerotis	*Naos*.
Denebola	*Ursa Majoris*.
Præsepe	*Procyon*.
Rigel	West.
Denebola	*Canopus*.
Rigel	Ocean.
Naos	*Canopus*.

(Too numerous to record).

Later—4 A.M.:—

From *Leo*	toward *Arcturus.*
Zenith	*Arcturus.*
Spica	*Mercury.*
Leo	*Mercury.*
Denebola	*Spica.*

These are a selection of the most prominent, all in this table having brilliant trails. The meteor appearing at $3^h 48^m$ near *Leo* shot to a point midway between *Orion's* head and the *Hyades* with terrific velocity and dissipated into cosmic debris with exceedingly brilliant greenish-blue light, estimated at twenty times the brightness of *Venus* at its maximum. The trail was probably $35'$ in width and 15° in length. The nucleus disintegrated at π *Orionis.* The trail extended beyond *Betelguese.* It remained in the same place for ten minutes, expanding in width to 2°. It then bent at right angles, assumed the shape of the letter F, and slowly widened to a thick **F**. The top bar became detached and floated to *Aldebaran*, where its pearly light went out. The upright widened and lingered 14^m, when it waned and expired. A large meteor, or fire-ball, with splendid streamer emerged from the high east at 4^h 4^m and moved to the shoulder of *Ursa Majoris* with great speed. The nucleus dissolved into intensely brilliant matter and vanished, but the glowing band widened to 1°, bent into the form of the Greek letter Ω and remained in view 6^m. These two were all that had persistent light, none of the others remaining visible more than from half a minute down to the fraction of a second. On November 13, 1833, the *Leonids* put on display at Niagara Falls, and from the accounts written the vision must have been superb. But how is it possible to surpass the unearthly splendor here amid the mountains? The solitude at the midnight hour is supreme, and the silence awful in its intensity. Then fill the expanse of the sidereal vault with shot and shell hurrying in all directions, bursting into brilliant streams here and there, emerging like the swords of marshaled hosts from darkening space,—war without a trace of sound; and the effect is overpowering to brain, sensation, and imagination. Here where the silence at the third hour is so profound that an alert imagery of mind calls up sounds from the cañon's depths and from opposite granite walls,—voices from the unknown in the night,—and where the stillness is so deep that if the axis of the Earth in its turning made sound it would be heard in this place, unique on earth, a bombardment of *Leonid* meteors is impressive beyond the power of language to portray.

At $1^h\ 54^m$ a cloud suddenly condensed round about a summit and obscured *Leo* until $2^h\ 53^m$. A few straggling meteors were seen emerging from the edges, but they were not counted. Omitting these 59^m the rate of fall was 657 meteors in 281 minutes or 2.34 per minute. The fall from 4^h to $4^h\ 20^m$ was five per minute, and the highest number seen at once was five. The trend of nearly all was from *Leo* to west and southwest, a limited number going to the north. When *Leo* was well up some appeared to drop into Los Angeles' distant electric sea of lights, others into the ocean, and still others into the gaping mouths of the cañons. All this was due to perspective; none reached the Earth. The mirror of the heliostat was set on the rising point of the radiant and spectroscope adjusted in the hope of securing spectra. None was obtained. No meteor came from the exact radiant. After the cloud dissolved, at $2^h\ 53^m$, all was clear until dawn. And thus passed the memorable shower of *Leonids* of 1901.

LOWE OBSERVATORY, ECHO MOUNTAIN P. O., CAL., NOV. 18, 1901.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1902.

BY MALCOLM MCNEILL.

JANUARY.

January, 1902, is not a favorable month for observation of the planets, with the exception of *Mercury* and *Venus*. Several of the others are in the western sky for a short time after sunset, but they are too low down to be easily seen.

Mercury passes superior conjunction with the Sun on January 1st and becomes an evening star, but does not get far enough away to be conspicuous until after the middle of the month. At the end of the month it remains above the horizon about an hour and a half after sunset. It passes *Saturn* on January 6th, *Jupiter* on January 9th, and *Mars* on January 23d. The last named conjunction is rather close, *Mercury* being less than the Moon's diameter south of *Mars*.

Venus is pre-eminently the evening star, remaining above the horizon several hours after sunset, and being also at its greatest brightness early in the month. It can be seen in full daylight at any time during the month when it is above the horizon. It gradually draws nearer the Sun, although its eastward motion among the stars continues until January 22d.

Mars is still in the southwestern sky just after sunset, but has for some time ceased to be conspicuous. It remains above the horizon about an hour and a half after sunset on January 1st, but can not easily be seen on account of its low altitude and faintness.

Jupiter and *Saturn* are still not far apart, but the eastward motion of the Sun among the stars is so much greater than that of the planets that it overtakes and passes them,—*Saturn* on January 9th, and *Jupiter* on January 15th. The planets then become morning stars, but do not attain a sufficient distance from the Sun to make themselves visible as morning objects until after the close of the month.

Uranus passed conjunction with the Sun early in December, and is now to be found in the east just before sunrise, but too low and faint to be easily seen.

Neptune is above the horizon most of the night in the region between *Taurus* and *Gemini*, but can not be seen without a telescope.

FEBRUARY.

The conditions for observation of the planets are even worse in February than they were in January, except perhaps in the case of *Mercury*. That planet comes to greatest east elongation on the morning of February 3d, and up to the middle of the month does not set for more than an hour after the Sun. The present greatest elongation is only 18°; but the planet is a considerable distance north of the Sun, and this in a measure compensates for the smallness of the distance. At the following greatest east elongation toward the end of May the distance will be 23°.

Venus is still very conspicuous as an evening star, at the beginning of the month setting about two hours after sunset on February 1st; but it has begun its retrograde motion among the stars, and this in combination with the eastward motion of the Sun brings the planet into inferior conjunction with the Sun on February 14th. It then becomes a morning star and will remain so until November 28th.

Mars is still east of the Sun, and is near the southwest horizon just after sunset; but the Sun is rapidly drawing nearer to it in their common eastward motion, so that at the end of the month their distance apart is only 6°. Throughout the month the planet is too near the Sun and too faint to be seen without a telescope.

Jupiter and *Saturn* become morning stars in January, and by the close of the month will rise an hour and a half to two hours before sunrise. *Saturn* precedes *Jupiter* more than half an hour, but the greater brightness of *Jupiter* will make him more easily visible.

Uranus rises two hours or more earlier than the last two planets, and may be found in the region between *Scorpio* and *Sagittarius*.

Neptune is in about the same place as the one it held in January, between *Taurus* and *Gemini*.

EXPLANATION OF THE TABLES.—The phases of the Moon are given in Pacific Standard time. In the tables for Sun and planets, the second and third columns give the Right Ascension and Declination for Greenwich noon. The fifth column gives the local mean time for transit over the Greenwich meridian. To find the local mean time of transit for any other meridian, the time given in the table must be corrected by adding or subtracting the change per day, multiplied by the fraction whose numerator is the longitude from Greenwich in hours, and whose denominator is 24. This correction is seldom much more than 1^{m}. To find the standard time for the phenomenon, correct the local mean time by *adding* the difference between standard and local time, if the place is west of the standard meridian, and *subtracting*, if east. The same rules apply to the fourth and sixth columns, which give the local mean times of rising and setting for the meridian of Greenwich. They are roughly computed for lat. 40°, with the noon Declination and time of meridian transit, and are intended as only a rough guide. They may be in error by a minute or two for the given latitude, and for latitudes differing much from 40° they may be several minutes out.

JANUARY–FEBRUARY, 1902.

PHASES OF THE MOON, P. S. T.

Last Quarter . . .	Jan.	1,	8^h	8^m	A. M.
New Moon . . .	Jan.	9,	1	15	P. M.
First Quarter . . .	Jan.	16,	10	38	
Full Moon . . .	Jan.	23,	4	6	
Last Quarter . . .	Jan.	31,	5	9	A. M.
New Moon . . .	Feb.	8,	5	21	
First Quarter . . .	Feb.	15,	6	57	
Full Moon . . .	Feb.	22,	5	3	

THE SUN.

1902.		R. A.	Declination.	Rises.	Transits.	Sets.
Jan.	1,	18^{h} 44^{m}	— 23° 4′	7^{h} 26^{m} A.M.	12^{h} 3^{m} P.M.	4^{h} 40^{m} P.M.
	11,	19 28	— 21 54	7 27	12 8	4 49
	21,	20 11	— 20 3	7 22	12 11	5 0
	31,	20 53	— 17 33	7 15	12 14	5 13
Feb.	10,	21 33	— 14 33	7 4	12 14	5 24
	20,	22 12	— 11 09	6 52	12 14	5 36
Mar.	2,	22 50	— 7 26	6 37	12 12	5 47

MERCURY.

Jan.	1,	18 43	— 24 50	7 34 A.M.	12 2 P.M.	4 30 P.M.
	11,	19 54	— 23 0	7 57	12 34	5 11
	21,	21 4	— 18 36	8 9	1 4	5 59
	31,	22 3	— 12 14	8 6	1 24	6 42
Feb.	10,	22 26	— 7 20	7 32	1 7	6 42
	20,	21 54	— 8 51	6 26	11 55 A.M.	5 24
Mar.	2,	21 29	— 12 40	5 36	10 52	4 8

VENUS.

Jan.	1,	21 45	— 13 47	9 51 A.M.	3 4 P.M.	8 17 P.M.
	11,	22 6	— 10 11	9 20	2 45	8 10
	21,	22 15	— 7 5	8 39	2 15	7 51
	31,	22 9	— 5 5	7 47	1 30	7 13
Feb.	10,	21 50	— 4 45	6 47	12 31	6 15
	20,	21 26	— 6 2	5 49	11 29 A. M.	5 9
Mar.	2,	21 12	— 7 56	5 2	10 35	4 8

MARS.

Jan.	1,	20 8	— 21 20	8 43 A.M.	1 27 P.M.	6 11 P.M.
	11,	20 41	— 19 29	8 29	1 20	6 11
	21,	21 13	— 17 17	8 13	1 13	6 13
	31,	21 44	— 14 46	7 56	1 5	6 15
Feb.	10,	22 14	— 12 1	7 37	12 56	6 15
	20,	22 44	— 9 4	7 17	12 46	6 15
Mar.	2,	23 13	— 6 0	6 56	12 36	6 16

JUPITER.

Jan.	1,	19 33	— 22 0	8 9 A.M.	12 52 P.M.	5 33 P.M.
Feb.	1,	20 4	— 20 44	6 35	11 21 A.M.	4 7
Mar.	1,	20 30	— 19 22	5 6	9 57	2 48

SATURN.

Jan.	1,	19 17	−22 6	7 55 A.M.	12 36 P.M.	5 17 P.M.
Feb.	1,	19 32	−21 37	6 6	10 49 A.M.	3 32
Mar.	1,	19 45	−21 9	4 27	9 12	1 57

URANUS.

Jan.	1,	17 10	−23 0	5 52 A.M.	10 29 A.M.	3 6 P.M.
Feb.	1,	17 17	−23 8	3 58	8 34	1 10
Mar.	1,	17 21	−23 12	2 12	6 48	11 24 A.M.

NEPTUNE.

Jan.	1,	5 59	+22 15	3 56 P.M.	11 16 P.M.	6 36 A.M.
Feb.	1,	5 56	+22 16	1 51	9 11	4 31
Mar.	1,	5 54	+22 17	noon	7 20	2 40

ECLIPSES OF *JUPITER'S* SATELLITES.

Jupiter is too near the Sun for observations of eclipse of satellites.

OBSERVATIONS OF THE VARIABLE STARS *W LYRÆ* AND *U_3 CYGNI.*

By ROSE O'HALLORAN.

According to the *Companion to the Observatory*, a minimum of the long-period variable, *W Lyræ*, was due on May 8th and a maximum on August 21st of this year. About sixty observations were obtained between April 21st and September 14th, but the following list includes only those showing distinct gradations and some seeming fluctuations. Clouds hindered observation from August 2d to 24th, but no doubt it was clear elsewhere during the time of the predicted maximum. Three days after that date the star had fallen to 9.4 magnitude, and unless the decline was very rapid, it is probable that the maximum occurred long before the date of prediction, as it had risen to eighth magnitude seven weeks previously. On April 21st and 26th, May 4th, 7th, and 8th it was invisible in a four-inch lens.

May 17. Equal to *t*, classed as of 12th mag.
" 23. Equal to *g* of 10th mag.

June	2.	Brighter than *g*, but less than *a* of 8.6 mag.
"	4.	Not so near the brightness of *a*, but equal to *p* of 9.4 mag.
"	10.	Equal to *e* of 8.8 mag.
"	21.	Brighter than *e*, but not fully equal to *a*.
"	23.	Equal to *a*.
"	29.	Brighter than *n* of 8.1 mag.
July	3.	Equal to *n*.
"	5.	Brighter than *n*.
"	7.	Equal to *n*.
"	8.	Brighter than *n*.
Aug.	1.	Equal to *n*.
"	24.	Less than *n*, equal to *p*.
Sept.	7.	Equal to *f* of 10th mag.
"	14.	Equal to *g*, which seems fainter than *f*, probably only one-tenth.

The comparison-stars used are those named in *Popular Astronomy*, No. 46.

*U*3 CYGNI.

The following observations of this *Algol* variable, discovered by Madame CERASKI on photographs taken at the Moscow Observatory, include but one minimum, which occurred on June 14th. The normal brightness of the star seems to be about 9th magnitude, but on June 15th, 21st, 22d, July 24th, August 1st it rose to nearly 6th magnitude.

May	23.	10:00 P. M.	Midway between *a* and *f* of the comparison-stars named in *Pop. Ast.* No. 67, and is accordingly of 8.9 mag.
"	24.	9:30 P. M.	
"	27.	10:00 P. M.	Nearly equal to *a* of 8.6 mag., but less than *g* of 8.2 mag.
"	29	9:40 P. M.	Equal to *f* of 9.2 mag.
"	30.	9:30 P. M.	Brighter than *f*, dimmer than *a*.
"	31.	9:30 P. M.	
June	1.	9:30 P. M.	
"	3.	9:30 P. M.	Not so near *a* in brightness, but still brighter than *f*. Night not very clear.
"	4.	8:53 P. M.	Still nearer to *f* than to *a*. Night clear.
"	5.	10:10 P. M.	Equal to *f*. Nights clear.
"	6.	9:00 P. M.	
"	7.	9:30 P. M.	
"	8.	9:00 P. M.	
"	9.	9:00 P. M.	
"	10.	8:45 P. M.	Brighter than *f*, not equal to *a*.
"	12.	9:00 P. M.	
"	14.	8:55 P. M.	It is barely discernible, probably of 12th mag.
"	15.	9:00 P. M.	It is equal to *a*, but less than *g*.
"	21.	9:15 P. M.	Nearly as bright as *a*.
"	22.	9.15 P. M.	

June	23.	9:00 P. M.	Equal to *d* of 9.6 mag.
"	24.	8:47 P. M.	Equal to *f*.
"	25.	8:50 P. M.	
"	26.	9:00 P. M.	Brighter than *f*.
"	27.	8:40 P. M.	Equal to *f*.
"	28.	9:00 P. M.	
"	29.	9:00 P. M.	Slightly brighter than *f*.
"	30.	9:00 P. M.	
July	2.	8:20 P. M.	
"	3.	8:40 P. M.	
"	4.	10:40 P. M.	
"	5.	8:50 P. M.	
"	7.	9:00 P. M.	Equal to *d*.
"	8.	8:45 P. M.	Brighter than *f*.
"	9.	8:30 P M.	Equal to *f*.
"	10.	8:30 P. M.	Brighter than *f*.
"	13.	9:00 P. M.	
"	18.	8:50 P. M.	Equal to *f*.
"	24.	8:50 P. M.	Nearly equal to *a*.
Aug.	1.	8:30 P. M.	

SAN FRANCISCO, September 21, 1901.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

OBSERVATIONS OF THE SPECTRUM OF *NOVA PERSEI.*†

At the time of the discovery of *Nova Persei*, the two single-prism spectrographs, with which all our low-dispersion photographs of the past ten years were secured, had just been shipped to Sumatra with the Crocker Eclipse Expedition. This shipment, including likewise several minor pieces of apparatus, left the spectroscopic resources of the Observatory temporarily inadequate for the efficient analysis of the star's light. The Mills spectrograph was too powerful for a qualitative study of the spectrum, and was limited in its action to parts of the blue and violet regions. Fortunately, we possess an abundant supply of large 60° prisms, both light and dense; and from these, in connection with the Mills spectrograph, new and efficient apparatus was designed and constructed as required.

In all the spectrographs employed, and described below, the collimator section of the Mills spectrograph was used; and the changes made relate entirely to the prism-boxes, cameras, and braces for supporting the cameras. It will be a convenience in the discussion of the observations to have some ready method of referring to the different combinations of apparatus.

The Mills spectrograph, as ordinarily employed, will retain its usual designation.

The other instruments, referred to as spectrographs I, II, III and IV, will now be described.

I. A brass prism-box, designed some years ago by Mr. CAMPBELL, for converting the Mills spectrograph into a one-prism instrument, was made ready for use by the evening of February 25th. It contained a single 60° light flint prism, and carried the regular Mills camera of 406^{mm} focal length. The instrument was found to give excellent definition from above λ 3700 to λ 5700.

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* Lick Astronomical Department of the University of California.

† Condensed from Lick Observatory *Bulletin*, No. 8.

By tilting the plate slightly, the definition was equally good from λ 4000 to λ 6000.

II. A large 60° dense flint prism, and a visually corrected triple lens of aperture 5^{cm} and focal length 53^{cm}, were mounted in wood, and attached to the collimator section of the Mills spectrograph. Most of the visual observations, and some photographs in the yellow and orange regions, were secured with this instrument. It replaced spectrograph I late in the evening of February 25th, and visual observations were obtained. The fine dark *D* sodium lines in the broad bright *D* band were seen at once, and with ease. The dark lines were compared directly with the bright *D* lines from an alcohol flame; and the star's lines were estimated by the two observers, respectively, to be displaced to the red about an eighth and a tenth of the distance between D_1 and D_2. These estimates—corresponding to radial velocities of 38 and 30 kilometers per second — were in close agreement with the photographic results [see page 231] secured a few nights later.

III. It was considered very desirable to obtain high-dispersion photographs of the *D* region. As the Mills spectrograph is limited to portions of the blue and violet, it was necessary to construct another prism-box and some auxiliary apparatus to secure the desired result. A prism-box to hold three very dense 60° prisms was constructed of wood by the Observatory carpenter, from designs by Mr. WRIGHT. The whole matter of designing, constructing, adjusting, and testing the apparatus required a day and a half. The instrument gave excellent results; no effects of flexure or shrinkage of the wood during the long exposures were visible. With the 406^{mm} camera, the separation of the *D* lines is 0.15^{mm}.

IV. Another box, similar in design to the one described in the preceding paragraph, was constructed for the purpose of photographing the *H* and *K* regions under high dispersion. It was lighter in some of its parts, and gave evidence of flexure. Results of value were secured with it, however. The three Mills prisms were used in this box, as the denser ones were entirely too yellow for work in the violet.

The comparison-lines used include those of iron, magnesium, sodium, hydrogen, and helium. Wave-length determinations have in all cases been based on the Hartmann-Cornu formula.

The spectrum was recorded from $H\delta$ to $H\beta$ on February

24th, with the Mills spectrograph. The $H\delta$, $H\gamma$, and $H\beta$ bands of hydrogen were bright and extremely broad, and were accompanied on their violet sides by very broad absorption-bands. Otherwise, the spectrum appeared to be strictly continuous. The absorption in the dark bands was only partial, so that the contrasts between bright and dark bands were very slight. The $H\beta$ bands were easily visible, but the $H\gamma$ and $H\delta$ bands were rather difficult, as a result of the too strong dispersion afforded by this instrument. The general character of the spectrum would have been shown much better by one-prism spectrograms.

On February 25th, photographs were secured with spectrograph I, and the star was observed visually with spectrograph II. Numerous bright and dark lines were easily observed; and while allowance must be made for the lower dispersion used, it is safe to say that in the region of the spectrum photographed on the preceding night, the bright bands and the contrasts between bright and dark bands were relatively much stronger. The bands appeared to be identical with those in the early spectrum of *Nova Aurigæ* (February, 1892), but in the earlier star the bands were much narrower and the contrasts were vastly stronger.

$H\alpha$ was very bright, and situated with reference to the artificial $H\alpha$ line in the same manner as the other hydrogen bands with reference to their normal positions. It was accompanied on the more refrangible side by its corresponding dark band. A very bright and broad band in the orange, presumably due to sodium radiations, was crossed by two apparently monochromatic dark lines. These were identified as D_1 and D_2. To the violet of this band was the usual absorption. It covered the normal position of D_3, but there is no reason to suspect that it related to the element helium. Besides the five well-known *Nova* bright bands in the region of λ 4860 to λ 5270 no further details could be observed visually, on account of the strong continuous spectrum which masked the fainter bands.

The spectrograms obtained on February 25th extended from λ 3830 to λ5700. One of these, enlarged 7-fold, is reproduced in the accompanying sheet of illustrations (Fig. 1). Perhaps the most striking features of the plates are the broad bright and dark *H* and *K* bands, the bright components being crossed by fine dark *H* and *K* lines (Fig. 5). The band at *H* is evidently the result of the superposition of the $H\epsilon$ (hydrogen) and *H* (calcium) bands. The fine *H* line is apparently not so black as the *K* line, though allowance must be made for the different densities of the negative at the two places.

The violet edges of the bright bands are the more sharply defined, except for the *K* band, in which the reverse is the case. The hydrogen bands are very broad and diffuse, and it is difficult to locate the positions of maximum with accuracy. There seems, however, to be a decided shift of the maxima to the violet of the normal positions of the hydrogen lines, by an amount greater than the probable error of measurement.

The next photographs with the same apparatus were secured on March 13th, by which time the spectrum had greatly changed. These changes appear to be more pronounced in the photographs taken on March 18th, and these two sets will be considered together. The spectrograms show the *K* band to have disappeared. Most probably the *H* band shared a similar fate, though it is impossible to prove this, on account of the superposition of the $H\epsilon$ band, referred to above. The fine *H* and *K* lines remain, but the absorption in the former appears to be less complete than before. The maxima of the bright hydrogen bands are shifted several tenth-meters toward the red from the normal positions of the hydrogen lines.

It is, however, in the dark bands accompanying the bright ones that the changes are most marked. The former broad, diffuse absorption-bands are replaced by multiple fine lines. Of these lines, the one of greatest wave-length is many times the most intense, and practically terminates the bright band with which it is associated. Two other lines were observed with certainty in many of the groups, and were suspected in all the groups, except $H\zeta$, where the spectrum was too faint for reliable observation.

The displacements of the principal dark lines from the normal positions of the hydrogen lines vary considerably from one end of the spectrum to the other, but seem to be very approximately proportional to the wave-lengths. In the following tables the means of the displacements for the two dates are given in the second column, while those computed on the assumption of direct proportionality to the wave-lengths are given in the third. The assumed proportion is represented by the equation $\Delta\lambda = 0.00505\lambda$.

Line.	Δλ Observed.	Computed.	O — C	Wt.
H_ζ	19.28 t. m.	19.64 t. m.	— 0.36 t. m.	1
H_ϵ	20.04	19.98	+ 0.06	1
H_δ	20.51	20.79	— 0.28	1
H_γ	22.18	22.91	+ 0.27	1
H_β	25.7	24.5	+ 1.2	½

The wave-lengths in the neighborhood of *Hβ* cannot be determined with great accuracy from these plates, on account of both the relatively low dispersion in that region of the spectrum and the unsatisfactory nature of the comparison-lines available for measurement. In the determination of the constant of proportionality the *Hβ* result was therefore given weight one-half. Considering the unsymmetrical distribution of light on the two sides of the absorption-lines, it is safe to say the residuals (O — C) are commensurate with the errors of measurement. The proportionality of the displacements of the dark hydrogen lines to their wave-lengths therefore appears to be a fundamental characteristic of the star's spectrum at this stage of its development.

We shall refer to the displacements of some of the other dark lines, the origins of which are open to little doubt. While the dark *H* and *K* bands were in evidence, they were displaced toward the more refrangible end of the spectrum by about 16.5 t. m. On account of the breadth of the bands, the measured displacement is liable to an error of perhaps two tenth-meters. The displacement computed by means of the proportionality assumed above is 20 t. m. The displacement of the dark *D* band (due to sodium), which will be referred to below, is 27 t. m. The error of measurement of the position of this band is influenced by its breadth, and to some extent by the sensitiveness-curve of the "isochromatic" plate used, which is very steep in this region of the spectrum. The tendency would be to make the measured displacement smaller. The computed displacement is 30 t. m.

The computed displacements given above depend, as has been said, on measurements of the fine hydrogen lines which developed after the calcium bands had disappeared, and probably after the spectrograms of the *D* band had been secured. It might therefore seem more reasonable to compare the displacements of the calcium and sodium bands with those of the diffuse bands of hydrogen which existed simultaneously with them, and resembled them somewhat in their general characteristics. The displacements of the hydrogen bands are —

Line.	$\Delta\lambda$
$H\delta$	— 19 t. m.
$H\gamma$	— 19
$H\beta$	— 24

From these we obtain the equation $\Delta\lambda = 0.0046\lambda$. The observed displacements, and those computed on this basis, are —

Line.	$\Delta\lambda$	
	Observed.	Computed.
K	— 17 t. m.	— 18 t. m.
H	— 16	— 18
D	— 27	— 27

The agreement is closer than that resulting from the first assumption. There is, then, no evidence that the position of the bands is affected by other considerations than that of wave-length.

The other features of the spectrum are shown in the reproduction of one of the plates of March 18th (Fig. 2), directly enlarged from the original negative.

The spectrograms for February 25th and March 18th are not strictly comparable on the red side of $H\beta$, for the reason that the plates used on the two dates were of different character. The earlier spectrogram was made on a Cramer isochromatic plate, and the later one on an ordinary Cramer Crown, a plate not sensitized to the lower rays. In all of the plates secured on March 13th and 18th, the region λ 4600–λ 4700 was over-exposed, and the details thereby destroyed.

During the early part of April the appearance of the spectrum was as is indicated in Figure 3. The triple absorption-lines referred to above had so decreased in intensity as to make their recognition very uncertain. A broad and diffuse absorption had developed in the neighborhood of the normal position of the three principal hydrogen lines. $H\zeta$ is just on the limit of visibility on the photographs, and no details can be observed with certainty in that region. The spectrogram of April 5th was made on a Cramer isochromatic plate, as was also that of February 25th, so that the two should be comparable.

It was not possible to observe the star every night over a long period of time, for the purpose of detecting rapid variations in the spectrum; such ones, for instance, as might accompany the more or less periodic changes in the star's brightness. In general, it was noticed during the spring months that the bright bands were relatively more intense at minima than at maxima of the star's brightness; that is, that the variations affected the continuous spectrum more than the bright lines. We recognize that physiological effects may play an important part in such estimates, however. Definite changes certainly occurred between April 1st and 5th. The bands λ 4629 and λ 4675, appearing on the spectrogram of April 5th, are not on that of April 1st; and the bands of April 1st at λ 4583 and λλ 4632–4661 are not recorded on that of April 5th. The band at λ 4675 was too faint to record itself on the earlier photograph. The changes described could be caused by variations in the relative intensities of one or two of the bands concerned.

The absence in Sumatra of the principal parts of the large visual spectroscope prevented visual measurements of the spectrum. There was little need for these, however, as the isochromatic plates afforded vastly more valuable observations down to and including the *D* region; and the *Hα* band was photographed with erythro plates, as well as observed visually. In February no bright bands were visible except those which have been mentioned above or described in the tables. As the star grew fainter, additional bands were observed. At the times of the last visual observations, on April 14th and 21st, essentially all the bands observed in the early sprectrum of *Nova Auriga* were present. Those at λ 5760, λ 5840, λ 6160, and λ 6300 were easily seen. The last photographic observation was secured on April 14th.

The spectrum was observed visually on two evenings, with instrument I, for the purpose of determining whether the light of the star was plane-polarzied to any extent. The slit was opened wide, and a Nicol prism was held in front of the eyepiece. As the prism was rotated, no narrowing of the lines, or other phenomena, were observed, except a slight darkening of the spectrum as a whole, due to the polarizing effect of the spectroscope. The results furnish no evidence of a Zeeman effect in the star, but in some respects the evidence is merely of a negative character.

The velocities in the line of sight determined from measurements of the fine dark *H* and *K* calcium lines on all the plates secured up to and including March 18th, with spectrograph I, are contained in the following table:—

Date	Plate No.	Velocities. H	K
Feb. 25	2023C	-4^{km}	$+6^{km}$
	2025C	$+2$	$+5$
	2026D	——	$+13$
Mar. 13	2049C	-6	$+13$
	2050D	$+22$	-4
Mar. 18	2056C	——	$+14$
	2057D	$+7$	$+7$
	Means	$+4.2^{km}$	$+7.7^{km}$

These values are corrected for the orbital motion of the earth, but not for diurnal motion and the curvature of the spectrum lines. These corrections are -0.2^{km}, and -0.3^{km}, respectively. Applying them to the mean of the individual determinations, we have $+5.7^{km}$ per second as the observed radial velocity of the star. This value was used in correcting all the wave-lengths determined with spectrograph I.

Recalling that the above individual results depend each upon measures of a single line, on plates secured with an instrument containing only one light flint prism, whereas the current results with the Mills spectrograph depend upon measures of many lines dispersed by three dense flint prisms, the linear values of the discrepancies are seen to be small.

A spectrogram of the *H* and *K* region secured on March 5th with spectrograph IV yielded the following velocities, from the fine dark lines:—

$$\begin{array}{rl} H, & +6.5^{km} \\ K, & +8.1 \\ \hline \text{Mean,} & +7.3^{km} \end{array}$$

A discrepancy of 2.5^{km} at $H\gamma$ corresponds in linear value to 1.8^{km} at *H*.

These dark lines were very narrow. The measured widths on the above plate were 0.22 t. m. and 0.28 t. m. respectively, including the effects of flexure of the instrument in broadening the lines.

Spectrograms of the *D* region were secured on February 26th, 27th, 28th, and March 3d, 14th, and 17th, with either low or high dispersion. While some of the low-dispersion plates are quite satisfactory, those of high dispersion are so much more so that results from the high dispersion alone will be considered. One of the latter was obtained on February 28th, and is reproduced in Figure 4. The position of maximum is apparently to the violet of the *D* absorption-lines; but the slope of the sensitiveness-curve of the plate, referred to above, would have a very strong tendency to shift the apparent maximum to the violet, so that it is impossible to locate the actual position of greatest intensity.

The radial velocities of the *Nova* determined from the *D* lines on these plates are as follows:—

Date.	Plate No.	Velocity.		Mean.	Corr. for Curv.	Red to Sun.	Velocity.
		D_1	D_2				
Feb. 28	2034C	+38.7	+33.8	+36.1	−2.7	−27.3	+6.1^{km}
Mar. 3	3040D	+33.8	+25.8	+29.8	−2.3	−27.0	+0.5

Mean velocity with reference to Sun, +3.3^{km}

In comparing these results for the *D* region with those secured from ordinary line-of-sight work in the violet region, it is necessary to bear in mind the matter of relative prismatic dispersion for the two regions. In the Mills spectrograph work at $H\gamma$ we should be satisfied if the discrepancy between the values secured from two plates, on each of which only two lines had been measured, were less, say, than 2½ kilometers per second. The linear value of the discrepancy between the above results, 6.1 — 0.5 = 5.6^{km}, would correspond to 2.4^{km} at $H\gamma$, with the Mills spectrograph.

As a check on these results, the *D* lines were measured on a spectrogram of the planet *Mars*, taken under similar conditions. The difference between the observed and computed velocities, —2.2^{km}, corresponds to — 1.0^{km} at $H\gamma$, and is satisfactory.

The *D* absorption-lines are very narrow. A comparison of their widths with those of the corresponding lines in the solar spectrum is not without interest. A measurement of one of the plates places their width at 0.8 t. m. The width of the solar lines according to ROWLAND'S tables is 0.17 t. m. It was considered better, however, to compare the two spectra under the same instrumental conditions. The widths of the *D* lines on a spectrogram of *Mars* and on one of the Sun were therefore measured, with the following results:—

Line.	*Mars.*	Width in Sun.	*Nova.*
D_1	1.0 t. m.	0.9 t. m.	0.8 t. m.
D_2	1.2	1.1	0.8

The solar and planetary lines are probably somewhat broadened by the presence of unresolved companions, but it is evident that the breadths in the two cases are of the same order. The last spectrogram of the *D* region, secured in the spring, was a low-dispersion one taken on March 17th. It showed the general features to have remained practically unchanged.

For convenience, the determinations of radial velocity referred to above are here collected:—

Spectrograph I, *H* and *K*, $+5.7^{km}$
Spectrograph III, D_1 and D_2, $+3.3$
Spectrograph IV, *H* and *K*, $+7.3$

In addition to the spectrograms on which these results depend, a number of others recorded the absorption-lines of sodium and calcium. Within the limits of error of measurement, all give accordant results. There is no evidence that the velocity is variable; and this view is strongly confirmed by the results of the summer series of observations, to be described below.

Spectroscopic observations of *Nova Persei* were discontinued from April 21st to July 9th, while the Sun was passing through this region of the sky. Our regret that the southern position of the Lick Observatory prevented observations in this period is coupled with the hope that the observatories of northern Europe were able to obtain a practically continuous series.

Our summer series of observations has been secured mainly with spectrograph I. The first observation of the series was made on July 9th. As announced by Professor PICKERING, the spectrum at this time was that of a nebula. The usual nebular lines are represented by broad bright bands. The several spectrograms obtained at well-distributed intervals since July 9th do not show that any pronounced changes have occurred in this time. Spectrograms covering the region $\lambda\,3800 - \lambda\,5900$ are reproduced in Figures 6 and 8.

The $H\alpha$ band is very bright, but no other details additional to those on the photographs have been shown by the visual observations.

A striking feature of the spectrum is the distribution of the light in most of the bands. In general, there is a maximum, considerably displaced to the violet of the normal position of the nebular line. This maximum is accompanied on its less refrangible side by a pronounced minimum. In most cases another

FIGURE 3.—*Nova Persei*, enlarged 7-fold. 1901 April 5.

Fig. 4.

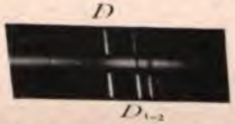

Fig. 5.

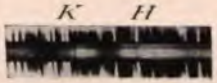

FIGURE 4.—*Nova Persei*, *D* region, enlarged 8-fold. 1901 March 3.
FIGURE 5.—*Nova Persei*, *H* and *K* region, enlarged 9-fold. 1901 February 25.

Fig. 6.

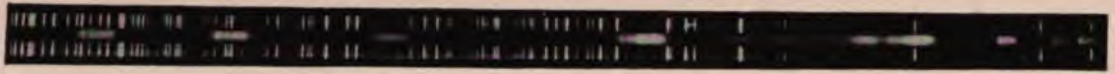

FIGURE 6.—*Nova Persei*, enlarged 7-fold. 1901 July 15.

minimum appears to the red of this, and in some of the bands there are additional minima. The one nearest to the maximum is in each case the strongest. While we have, of course, no knowledge as to the origin of these minima, their appearance certainly suggests that they are absorption phenomena, and they will be referred to as such. Though most of the bands conform to a general type, they are not by any means duplicates of one another. In some cases the principal absorption-line alone was identified with certainty, while in others lines apparently not belonging to the series were strongly suspected. In a number of instances the appearance of the bands was indicative of such complexity of structure as to make it impossible to consider more than their general features in a preliminary study of this sort. It is quite possible that some of the absorption-lines are due to gases in the atmosphere of the star, which are not directly involved in the production of the bands. In fact, this actually occurs in the case of the *D* sodium lines and the *H* calcium line. The latter appears as an absorption-line in the band λ 3947–λ 3988. There is little reason to doubt that its companion, the *K* line, is absent only by reason of the fact that there the calcium vapor has nothing to absorb.

Another cause of complexity is the overlapping of bands. This occurs in at least three cases:—

1. The bands corresponding to λ 4340.6 ($H\gamma$) and λ 4363 (nebular line) are involved in the composite band λ 4325–λ 4385.

2. Those belonging to the nebular lines λ 4685.9 and λ 4713.2 (helium) are superposed in the band λ 4669–λ 4746. There are, in fact, circumstances which indicate the presence of still another component in this band. It will be seen by referring to Table IV that there is a maximum at λ 4714, brighter than the one at λ 4703, and which cannot be accounted for by the superposition of the two bands to which reference has been made, assuming them to be of normal type. In addition, there are absorption-lines at λ 4719 and λ 4725.7. These effects would be produced by a superposed band of the regular type corresponding to a line of normal wave-length λ 4724. Moreover, judging from the other bands, the band whose maximum is at λ 4703 should vanish at about λ 4733, whereas the composite band in question extends to λ 4746. The extension may, however, be due to the nebular line λ 4743±, the presence of which is partially indicated by an absorption-line at λ 4736. While the complexity of the band is

such that a final statement of its composition is impossible without further study, the hypothesis of a line normally at λ 4724 is advanced as furnishing a plausible explanation of the structure of the broad band.

3. The band λ 3953–λ 3984 was supposed at first to be the broadened *H*ε line; but on this supposition the line is unduly strong. The *H*γ band is very bright, *H*δ is fairly bright, and the λ 3969 is very bright, whereas *H*ζ and the rest of the ultra-violet hydrogen series do not appear. Furthermore, the displacement of the maximum of this band to the violet of the normal position of *H*ε was greater by about two tenth-meters than that of the other maxima in this region of the spectrum. Some spectrograms of well-known planetary nebulæ recently secured by Mr. WRIGHT fully explain these peculiarities. In all previous work on the nebulæ, the line recorded at this point in the spectrum has been regarded as single, and has been assumed to be *H*ε. The line is in reality a wide double, as shown in the reproduction of the spectrum of N. G. C. 7027 (Fig. 7). The component of greater wave-length is the *H*ε hydrogen line, at λ 3970.2; it is very faint. The more refrangible component, at λ 3967.6, is much the brighter of the two, and appears to be a characteristic strong nebular line, not previously observed. The positions and relative intensities of these lines leave no doubt that the *Nova* band at λ 3453–λ 3984 corresponds almost entirely to this nebular line at λ 3967.6, and is scarcely influenced by the *H*ε radiations.

In order to investigate the displacements of the maxima of the star-bands, from the normal positions of the lines in the nebulæ, it was found necessary to make more accurate determinations of the wave-lengths of some of the nebular lines than were available. An investigation with that end in view was therefore undertaken by Mr. WRIGHT, and some of the preliminary results will be used in this paper. The following table gives the displacements of the maxima and of the absorption lines of all the bands of the *Nova* which have been identified as being of nebular origin. The first column contains the normal wave-lengths of the lines in nebular spectra, the second the displacements of the maxima, and the third the computed displacements on the assumption of proportionality of displacement to wave-length, according to the empirical formula $\Delta\lambda = -0.00212\lambda$. The following four columns contain the measured displacements of the absorption-lines which appear to belong to the bands.

Positive and negative signs indicate displacements toward the red and violet ends of the spectrum, respectively. Both the maxima and the minima appear to be displaced in proportion to their wave-lengths. The observed widths of the bands are given in the eighth column, as far as they can be determined; but it should be said that the photographic widths are affected both by their intensities and by the sensitiveness-curve of the plate. The red edge of the band at λ 5876 is practically at the limit for isochromatic plates. The wave-lengths of the principal bright bands observed in *Nova Aurigæ* in August, 1892, by Mr. CAMPBELL, are contained in the last column. That star was of the 10.5 magnitude, and the photographs did not cover the ultra-violet regions.

TABLE I.

Wave lengths in the Nebulæ.	DISPLACEMENTS.						Width of Bands.	Principal Bands *Nova Aurigæ*.
	Max. Obs'd.	Max. Com'd.	Min. Obs'd.	Min. Obs'd.	Min. Obs'd.	Min. Obs'd.		
3868.9	− 8.7	− 8.2	−4.8	+0.8	+6.0	+10.0	31	
3967.6	− 8.6	− 8.4	−4.9	+1.1*	(+3.8)		31	
4101.9	− 8.2	− 8.7	−4.8	+1.	+7		36	4098
4340.6	− 9.4	− 9.2	−5.					4336
4363.3	− 9.7	− 9.1	−5.2	+1.4			33	4358
4471.6	− 9.6	− 9.5	−5	(0)			34	4466
4643±	−11	−10	−8					4630
4685.9	−10	−10	−5	+3		+10		4681
4713.2	−10	−10	−5					471-
4743			−6					
4861.5	− 9	−10	−6	+1	(+7)	(+11)	33	4857
4959.0	−11	−11	−6	+2			34	4953
5007.0	−11	−11	−6	+1			38	5002
5752	−11	−12	−6			+16	43	5750
5875.9	−13	−12	−7	+1			40	
6563†								

Parentheses indicate that the line was only suspected. The absorption in most of the lines is incomplete, so that the bringing out of any particular one is largely a matter of exposure and development. It is quite possible that other lines exist which will appear in a final comparison of all the sprectrograms secured.

The nebular character of the *Nova* spectrum at present is evident from the measures published in the tables, and may be seen at a glance by comparing Figures 6 and 7. All of the principal bands correspond to lines known to exist in the nebulæ.

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*The dark line *H* falls in this place, and determines the exact position measured.

†The very bright *Hα* band was observed visually, but no attempt was made to photograph it in the summer series.

A comparison of the first and last columns of Table I shows that the spectrum of *Nova Aurigæ* is very closely related to that of *Nova Persei*. The absence of the bands at λ 5876 and λ 6563 from the former star is no doubt explained by the fact that it was more than four magnitudes fainter than the present star; and it is probable that the bands at λ 3869 and λ 3968 were not recorded in 1892 because no auxiliary correcting-lens was used to eliminate the chromatic aberration effects of the 36-inch objective. The bands in the present *Nova* are vastly wider than in that of 1892, and the distribution of light within the bands seems to be different. The positions of corresponding maxima differ about five or six tenth-meters in the two cases. Perhaps the most remarkable features of the 1892 spectrum were the bands observed by Mr. CAMPBELL at λ 4358 and λ 5750. The λ 4358 band, in August, 1892, was estimated to be at least eight times as bright as the *H*γ band, but in November, 1894, it had become fainter than *H*γ; and the band at λ 5750, so easily observed in 1892, had become extremely difficult in 1894 (*Astrophysical Journal*, Vol. I, pp. 49–51). These two bands are now very prominent in *Nova Persei;* and it is probable that they will diminish in brightness, as in the case of the earlier star. Corresponding to these two bands, there are faint lines in the well-known nebulæ.

The radial velocity of *Nova Persei*, determined from the *H* absorption-line of calcium, was + 6^{km} on July 15th, and + 12^{km} on July 24th. The mean of the two determinations is in satisfactory agreement with the value, 5^{km}, afforded by the *H* line in the spring series.

At the time of the spring observations, the *D* absorption-lines occupied positions near the middle of the broad *D* bright band, as shown in Figure 4; and the D_3 comparison fell near the more refrangible edge of the band. In the summer observations, the D_3 comparison-line (Fig. 8), falls near the middle of the bright band, and the sodium comparison-lines are situated at the extreme red edge of the band. A long exposure made on August 12th records this bright band to about the wave-length λ 5902, and the sodium *D* absorption-lines are clearly shown to be present. Within the limits of error of measurement, they occupy exactly the same positions as in the spring observations. Corroborative evidence is thereby afforded that the radial velocity of *Nova Persei* has been practically constant.

A number of the bands have recently been photographed with a dispersion of three dense flint prisms. They all appear to have the same general features, as follows: A pronounced maximum is near the violet edge of the band, flanked on either side by a subordinate maximum. To the red of this group is a broad minimum, or absorption-line, while still farther to the red is a group of maxima and minima giving the appearance of four absorption-lines. With low dispersion this group was observed in most of the bands as a broad and diffuse absorption-line (see Table I, column 5). An intensity-curve drawn from a Mills spectrogram of the band at $\lambda 435$ is reproduced in Figure 9. Further than to note these general characteristics, the spectrograms referred to have not been studied.

The bearing of the foregoing observations upon the various theories of new stars is reserved for a future paper.

It is greatly to be regretted that the delicate details of the original negatives are so largely lost in the reproductions.

Acknowledgments are due to Dr. H. M. REESE for assistance in taking many of the photographs and in reducing some of the measures.

W. W. CAMPBELL,
W. H. WRIGHT.

September 12, 1901.

MOTION IN THE FAINT NEBULA SURROUNDING *NOVA PERSEI*.*

A negative was secured with the Crossley reflector on the nights of November 7th and 8th of the region about *Nova Persei*, having a total exposure of $7^h\ 19^m$. Very faint nebulosity is shown on all sides of the *Nova*, the most pronounced being to the south. Several broken and irregular streamers are shown in this direction to a distance of 6′ from the *Nova*, while the brightest mass of all is very close to the star on the southwest side, so close as to appear to join it. There are several quite well marked condensations in the form of wisps on the outer edge of the nebulous area to the south. This series of wisps is concave toward the *Nova* and forms a streamer which may be the outer portion of a spiral or a portion of a conic section other than a circle. The end of this streamer farthest from the star is the strongest and is of a very peculiar forked form. To the north there is considerable very faint nebulosity, but without any particular structure.

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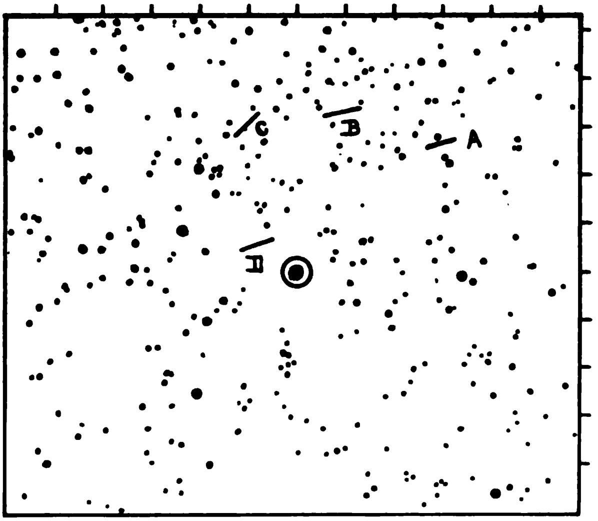
* Abstract from Lick Observatory *Bulletin*, No. 10.

The bright mass about 6′ south of *Nova* was discovered by Professor Max Wolf* on negatives taken with his doublets on August 23d with an exposure of four hours.

This and a large amount of new nebulosity were photographed by Mr. Ritchey† at the Yerkes Observatory with a two-foot reflector of short focus, on September 20th.

A comparison of the negative taken with the Crossley reflector and the reproduction of one secured by Mr. Ritchey showed that remarkable changes had occurred in the positions of the four most pronounced condensations during the interval of forty-eight days. The accompanying diagram shows the position of the *Nova* and surrounding stars. The lines marked A, B, C, D, represent the amount and direction of motion of the four condensations already referred to. The left-hand, or northwest, end of the line shows the position of the center of figure of each condensation on September 20th, while the right-hand, or southeast, end shows its position on November 7-8th. It will be seen that in the interval each mass suffered a displacement of about 1½′, or at the rate of 11′ per annum. The directions of motion do not indicate clearly the general character of motion of the nebula; it is certainly not radial, but further than this it is not possible to say. The observed motions may be irregular, spiral, or recti-



**Astronomische Nachrichten*, No. 3736. †*Astrophysical Journal*, XIV, 167.

linear. The photographs, as well as the visual observations, show no appreciable proper motion in *Nova*, nor does there appear to be any abnormal parallax to the star. Hence if we assume that the *Nova* and its nebulous envelope is no farther away than the *nearest* known fixed star, the observed displacement shows a velocity of about 2,500 miles per second. Should the nebula be at a *greater* distance, or not be moving directly across the line of sight, this velocity, great as it is, would be still larger.

The enormous velocity indicated in the nebula leaves little doubt that it is closely connected with the outburst which caused this star to become so brilliant.

Whether the nebula is a product of the outburst or was present at the time, there seems no way of telling at present.

Several theories have been advanced to account for the phenomena witnessed in connection with new stars. One of these, which has found many supporters, is that a collision or near approach has taken place between two solid and comparatively cool bodies, or that a solid body has encountered a nebula or swarm of meteors. The evidence of such excessively great velocities strengthens the belief that, whatever the cause, the outburst is due to some great catastrophe.

A photograph was secured with the Crossley reflector on the nights of November 12th and 13th with a total exposure of ten hours. The plate used was more rapid than the first, and the resulting negative shows greater strength in the nebula as well as a greater amount of the structure. The nebulosity does not extend appreciably farther from *Nova* than in the earlier photograph, however.

Mr. JOEL STEBBINS, Fellow in Astronomy, assisted in obtaining the photographs with the Crossley reflector.

C. D. PERRINE.

MOUNT HAMILTON, CALIFORNIA, November 10, 1901.

Postscript.— It is a pleasure to add that on November 11th (the day following the announcement of the above discovery) confirmation in the form of the following telegram was received through Harvard College Observatory:—

> "RITCHEY states photograph Yerkes, November 9th, confirms large-motion nebula near *Nova*."

EXTRACT FROM A LETTER FROM OTTO STRUVE.

[The following is an extract from a letter which I have recently received from OTTO STRUVE. It is of interest, in giving his latest views respecting the desirability of obtaining the systematic corrections of double-star measures by the observation of artificial double stars.—W. J. HUSSEY.]

KARLSRUHE, 1901, October 27.

Dear Sir:—Accept my heartiest and sincerest thanks for your observations of and treatise on the Otto Struve stars, which you have most kindly sent to me in volume V of the *Publications* of the Lick Observatory. The consistent and rapid execution of the work, both in respect to making the observations and in the collection of those made by other observers, awakens my full astonishment. I have read your introduction through carefully with lively interest, and I thank you for it. What you have said in it about the systematic errors in my measures and the corrections for the same, which I occupied myself so long to ascertain, has my full assent. But in this connection it has occurred to me that I have not perhaps expressed myself clearly enough in my publications on this subject to the effect that I myself am of the opinion that the correction formulas, which are given by the mean results of the many years of effort to determine the systematic errors, may perhaps not be equally applicable to all periods of my measures. It seems to me probable that my measures experienced a marked inexplicable change not only about 1843, but that they also changed more or less at intervals during the half-century over which they extend, possibly corresponding to physical conditions. The existing materials — the measures of artificial double stars — are unfortunately not sufficient to trace out such changes. For my own measures it is not possible to obtain this certainty. But it lies near to my thoughts to call the attention of future observers to such changes and to recommend them to follow your example, to limit sharply the programme of measures, to complete it in the shortest possible time, and in the same period to determine also the systematic errors by the measurement of artificial double stars.

. . . .

In closing this letter I must ask your pardon that in answering your letter I make use of my mother-tongue, the German. Formerly it was very easy for me to write English and to speak it, but now it would be a severe task for a man standing in his eighty-third year.

Receive, dear sir, with my thanks my heartiest wish that you may be permitted to enrich astronomy many fold through similar works.

OTTO STRUVE.

NEW DOUBLE STARS. *

For somewhat more than two years I have devoted a portion of my time to the examination of large numbers of stars in various parts of the sky for the purpose of detecting hitherto unknown double stars. This search has resulted in the discovery of five hundred new pairs, having distances under five seconds of arc. These new pairs are being announced, a hundred at a time, as rapidly as sets of measures for them can be obtained. Observations of three hundred have already been published, and those of a fourth hundred are now in the hands of the printers.

The following table gives the classification of the stars with respect to the distances between their components:—

	1st Cat.	2d Cat.	3d Cat.	4th Cat.	Total.
0″.25 or less	3	9	5	13	30
0 .26 to 0″.50	12	16	12	30	70
0 .51 to 1 .00	24	22	20	24	90
1 .01 to 2 .00	29	26	25	18	98
2 .01 or more	32	27	38	15	112

According to this table 72 per cent. of these four hundred pairs have distances not exceeding 2″; 48 per cent. not exceeding 1″; and 25 per cent. not exceeding 0″.5.

I have endeavored to conduct my search for new pairs in a systematic manner, and in the end it is hoped that the work will afford considerable data concerning the distribution of the close double stars in various parts of the sky and of their numbers in respect to magnitude and in proportion to the total number of stars examined.

In examining large numbers of stars with high powers under good atmospheric conditions in various parts of the sky, one is impressed with the fact that the close double stars, say those having distances under 5″, are not distributed over the celestial sphere strictly proportionally to the number of stars to a given magnitude, say 9.1. In some places one may examine all the stars to this magnitude over a large area without finding any new

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* From Lick Observatory Bulletin No. —.

pair and but few known ones, while in other regions the double stars are comparatively numerous. This probably has a physical significance. Apparently the conditions which determine the existence or non-existence of double stars in given directions prevail throughout spaces of enormous extent. W. J. HUSSEY.

PUBLICATIONS OF THE LICK OBSERVATORY, VOL. V.

Volume V of the *Publications of the Lick Observatory* has recently been distributed. The volume contains the micrometrical observations of the double stars discovered at Pulkowa, better known, perhaps, as the OΣ stars, made by Astronomer W. J. HUSSEY with the 36-inch and 12-inch refractors of this Observatory since the beginning of 1898, together with the mean results of the previous observations of these stars.

In all, 547 stars were observed, requiring 2,109 measures, not counting 65 examinations of stars found single. In the course of these observations, Professor HUSSEY found new companions to the stars OΣ 190, OΣ 247, OΣ 283, OΣ 351, and OΣ 476. By the discovery of the new companions to OΣ 351 and OΣ 476, these stars become the closest visual triples at present known.

The introduction states the motive of the work, describes briefly the instruments used and the methods of observing, and gives a general account of OTTO STRUVE'S discoveries and measures, and his efforts to eliminate the systematic errors known to exist in his work.

In connection with the collected measures of each star, Professor HUSSEY gives such discussion of the character of the star's motion as is warranted by the existing material, and complete references to the original sources of the observations.

The stars are arranged in the order of their numbers in the body of the work, and a catalogue is appended giving them in the order of Right Ascension.

The volume gives practically a complete history to date of the Otto Struve stars, and in a form that will, it is thought, prove exceedingly convenient and valuable to all who are interested in the subject of double stars.

The volumes addressed to our foreign correspondents have been distributed through the kind offices of the Smithsonian Institution, and will reach their destinations in due time.

W. W. CAMPBELL.

DUPLICITY OF THE PRINCIPAL COMPONENT OF β 986.

In measuring β 986 with the 36-inch telescope in September of the present year, I noticed that the brighter star is a very close double. I secured measures of it, and of the β pair on three nights, as follows:—

A and *B* (new) 9.0 — 9.0

1901.742	129°.2	0″.15	1900	3 +
.770	125 .5	0 .16	1500	3
.781	131 .5	0 .17	1500	3
1901.76	128°.7	0″.16		

A B and *C* = β 986. 8.5 — 12.3

1901.742	238°.4	4″.11	520	3 +
.770	241 .5	4 .40	1000	3
.781	239 .3	4 .42	520	3
1901.76	239°.7	4″.31		

There are but two other sets of measures of the β pair, one by BURNHAM, with the 18½-inch telescope of the Dearborn Observatory, and the other by WILSON, with the 15-inch telescope of the Carleton College Observatory. The new pair, at the present distance, would be exceedingly difficult to see with either of these instruments.

R. G. AITKEN.

November 14, 1901.

"THE STARS: A STUDY OF THE UNIVERSE." *

Professor SIMON NEWCOMB has just published a volume of extraordinary interest, both to the professional astronomer and to the general reader, under the above title. Some portions of the book have been published in the *Popular Science Monthly* for 1900 and 1901, but the gaps in the magazine series have been filled in to make a complete treatise.

It is plain that no greater subject exists than that of the stars, their history, and their present distribution throughout space, and it is a most fortunate circumstance that the greatest living astronomer has undertaken to treat this subject.

It is planned that a review of the book shall appear in the next number of these *Publications*.

W. W. CAMPBELL.

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*Octavo, 333 + x pp. New York: G. P. PUTNAM'S SONS. London: JOHN MURRAY.

ASTRONOMICAL TELEGRAMS.

MT. HAMILTON, CAL., November 10, 1901.
Professor E. C. PICKERING, (Sent 11:45 A.M.)
Harvard College Observatory,
Cambridge, Mass.

From Crossley photograph PERRINE finds that four principal condensations of the faint nebula surrounding *Nova Persei* moved southeast one minute of arc in six weeks.

(Signed) W. W. CAMPBELL.

CAMBRIDGE, MASS., November 11, 1901.
Professor W. W. CAMPBELL, (Received 5:20 P.M.)
Lick Observatory, Cal.

RITCHEY states a photograph taken at the Yerkes Observatory on November 9th confirms the large motion of nebula near *Nova Persei*. (Signed) E. C. PICKERING.

BOSTON, MASS., November 13, 1901.
To Lick Observatory, (Received 9:30 A.M.)
Mt. Hamilton, Cal.

HALE telegraphs that RITCHEY finds *Nova Persei* nebula probably expanding in all directions. Certainly in southern half.

(Signed) JOHN RITCHIE, JR.

Dr. W. W. CAMPBELL, Director of the Lick Observatory, was elected Foreign Associate of the Royal Astronomical Society, at the meeting held in London on November 9th.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

MR. FRANK B. LITTELL has been appointed Professor of Mathematics in the United States Navy.

The Board of Visitors of the United States Naval Observatory has made a report to Secretary LONG, and the following extracts are taken from newspaper accounts of the report:—

"It is recommended that no Astronomical Director be appointed at present, as a dual headship has been found to work unsatisfactorily, and under the existing law the appointment of an astronomer as sole director of the observatory — which the board considers the proper solution of the question — is impracticable. Vacancies should not be filled among assistant astronomers nor among professors of mathematics in the navy without examination for each vacancy occurring. No distinction should be made between employees of the observatory and other applicants. The responsibilities of the positions of assistant astronomer and professor of mathematics are distinctly different from those of a computer, although much of the required experience may properly be maintained in connection with the latter position and be credited in the examinations for the higher positions. As far as is consistent with the routine needs of the institution, the duties of the computers should be so arranged as to encourage them to prepare for advancement within the observatory itself. In no case should appointments be made to the observatory merely by transfer from other bureaus or offices in the service, nor should appointments be made, even temporarily, without competitive examinations.

"As every other prominent observatory is under the direction of an astronomer, it is our judgment that the law limiting the superintendency to a line officer of the navy should be changed so as to provide that the official head of the observatory — perhaps styled simply 'The Director'— should be an eminent astronomer, appointed by the President, by and with the advice and consent of the Senate, holding this place by a tenure at least as permanent as that of the Superintendent of the Coast Survey or the head of the Geological Survey, and not merely by a detail of two or three years' duration. Only in this way can there be a continuous and effective policy of administration which will assure astronomical work of a high order. In rank, salary, privilege, and prestige he should be superior to any officer on the ground.

"The limitation in the selection of assistants should also be removed, and the assistant once appointed should be secure against detachment or removal, except by the action, for cause, of the Director.

"The institution should be related to the Navy Department, if continued under its control, in some such way as the Royal Observatory at Greenwich is related to the British Admiralty. It should be put under the control of the Secretary direct, and not through a bureau as at present."

Mr. J. L. E. DREYER, of Armagh, Ireland, has called our attention to an error in these *Publications*, No. 79, page 130, concerning the brightness of TYCHO's star when first seen by him. By way of correction we reprint a letter of Mr. DREYER'S, published in the April number of *The Observatory*, page 166:—

> "In the article on 'Temporary Stars,' in your March number (p. 126), you say that 'TYCHO's star, in 1572, was first seen as bright as *Jupiter*, and quickly increased, so that it became equal to *Venus*.' Allow me to point out that the star, when first seen by TYCHO, was brighter than *Jupiter* at minimum distance, and was as nearly as possible equal to *Venus* at its maximum brightness. The few observers who saw it some days earlier than TYCHO did not say anything about its magnitude.
>
> "The erroneous statement that the star was at first only equal to *Jupiter* appears in a few modern books (even in YOUNG's 'General Astronomy'), and has probably originally arisen through careless reading of TYCHO's own words. As some hypothesis or theory about the nature of these bodies may some day be founded on the alleged slow increase of TYCHO's star, it may be well to point out the mistake. I have given a full review of the literature on this star in my 'Tycho Brahe,' chapters 3 and 8.
>
> "Whether really 'TYCHO's star remains in the heavens, a shadow of its former greatness,' is somewhat uncertain. No doubt there is a small star within a minute of arc of the most probable place of the *Nova*, but it is obvious that we cannot be sure of the identity of the two."

Mr. ANDREW GREIG has kindly sent the following account from the *Cape Argus*, of the presentation of a new telescope to the Royal Observatory, Cape of Good Hope:—

> "Few events have ever taken place in the southern hemisphere of greater direct scientific significance than that which was the occasion on the 26th of September last, of the delightful function at the Royal Observatory. This was the unveiling by his Excellency the Governor of the inscription-stone of the new Victoria telescope, which has been presented to the Observatory by Mr. FRANK MCCLEAN, LL. D., F. R. S. The large telescope is mounted in a circular room surmounted by a movable dome. This dome is in sliding sections, thus admitting of the telescope being pointed in a few seconds to any quarter of the sky; and nothing has been left undone to make the building and telescope a worthy memorial to her late Majesty. Suitable smaller rooms are provided in the building for the various operations necessary in connection with the work of examining, comparing, and photographing the spectra of luminous celestial bodies. The adjuncts and fittings throughout the whole building are of the most approved type, and are thoroughly in accordance with the munificence of their donor. The principal speech

was made by Sir DAVID GILL, H. M. Astronomer, who delivered an interesting address on the old and the new astronomy, and narrated the circumstances under which Mr. McCLEAN had presented 'The Victoria Telescope' to the Cape Observatory."

NOVA PERSEI.—Since the middle of July the brightness of the new star in *Perseus* has remained constant at about 6½ magnitude. Astronomers are still interested in the wonderful object, and the observations and investigations of the last few months have brought out some interesting facts.

Light Curve.—Under date of June 5th, Rev. Father HAGEN, of the Georgetown College Observatory, published a discussion of all the observations of brightness made between February 22d and May 1st. The observations were divided into various classes and plotted on a large scale. The resulting light-curve confirms in general that deduced by the writer from his own observations and published in number 79 of these *Publications.* The conclusions reached by HAGEN are as follows:—

"As to the *shape* of the light-curve, besides the general decline of magnitude from the first to the sixth, there are three minima,—March 19th, 22d, 25th,—which seem to be established beyond doubt, while later ones for March 28th, April 2d or 3d, 6th or 7th, and 10th or 11th, are indicated with great probability. Four more minima seen to have occurred until the beginning of May, which, however, could not be located exactly on account of the scarcity of the available observations. Previous to March 19th the minimum of the 16th seems to be real, and perhaps four or five more, preceding each other in periods of a little over two days.

"The apparent small oscillations from March 3d backward to February 24th may be the effect of systematic differences between the observations. The period of oscillation is about one day, and the same observers are generally represented in the same phase. Should additional publications prove them to be real, then the general character of this light-curve would exhibit a *harmonic change of brightness of the Nova with a period gradually lengthening from one day to four and a half or five days.*"

Dr. WILSON, of the Goodsell Observatory, has taken up also the investigation of the light-curve of *Nova Persei*, and two installments of a continued series of articles on the subject have appeared in the October and November numbers of *Popular Astronomy.* All the published observations have been collected, classified, discussed, and plotted, and the resulting curve, covering the period from time of discovery to April 25th, has been published as a frontispiece in the November number. We give below a tabulation of the maxima and minima as read from the three curves mentioned:—

MAXIMA.			MINIMA.		
HAGEN.	WILSON.	TOWNLEY.	HAGEN.	WILSON.	TOWNLEY.
Mar. 12.4	Mar. 12.5		Mar. 13.4	Mar. 13.5	
14.7	14.8	Mar. 14.5	16.3	16.4	Mar. 16.5
18.0	18.1	[18.7]	19.3	19.4	[20.9]
20.5	20.7		22.3	22.1	
23.6	23.0	[23.4]	25.5	25.5	25.4
27.0	27.0	27.0	29.0	28.7	29.2
31.4	31.3	31.2	Apr. 3.0	Apr. 3.2	Apr. 2.7
Apr. 4.8	Apr. 4.7	Apr. [4.8]	7.0	7.2	6.9
9.0	8.9	9.0	10.8	11.3	[11.2]
[12.5]	12.8	13.3	16.0	16.4	15.7
18.4	18.2	18.2	21.3	21.3	20.9
23.3	23.4	23.7	25.7		26.2
27.7		28.0			30.5

The maximum of April 12th cannot be read accurately from HAGEN's chart. The values in brackets have few or no observations to support them.

The above tabulation shows conclusively that the period of the star lengthened during the latter part of March and during April. Subsequent observations show that the period continued to lengthen with a decreasing range, until it finally died out about the middle of July. Since then the brightness has been practically constant at about 6½ magnitude.

Spectrum.— The spectroscope has provided much interesting material. During the spring months the spectrum was quite similar to that of *Nova Aurigæ* during the early months of its appearance. Bright and dark lines were both present and many changes have been recorded. That these changes in the spectrum were connected with the observed variations in brightness seem very probable, but most of the spectroscopic observations are too scattering to be of much use in comparing the changes with those of the star's brightness.

E. VON GOTHARD, however, has published in *Astronomische Nachrichten*, No. 3713, under the title of "Periodische Veränderungen in Spectrum der *Nova Persei*," some results of particular interest. His observations yielded two types of spectra, one in which the continuous spectrum was very strong, and the other in which the continuous spectrum was weak and several bright lines were very prominent. He calls this latter a "gas spectrum." The first type of spectrum was seen very clearly on March 31st, April 8th, 18th, 27th, and the second type on April 6th, 11th, 21st, 22d, 25th, 29th. A comparison of these dates with those of the table above show that the dates of the first type of spectrum coincide with the maxima of brightness and those of the second type with the minima. I wish to acknowledge that Mr. RALPH H. CURTISS, Fellow of the Lick Observatory, first called my attention to VON GOTHARD'S article and the coincidences noted above.

During June the spectrum changed gradually to that of a planetary nebula.

Motion in the line of sight.— The observations of CAMPBELL and WRIGHT at the Lick Observatory, show that the *Nova* has a small and practically constant motion in the line of sight. There is no indication of orbital motion.

Photographs.— Negatives taken by Dr. Wolf at Heidelberg, Mr. RITCHEY, of the Yerkes Observatory, and Mr. PERRINE, of the Lick Observatory, show the presence of a faint nebulosity in the neighborhood of the new star. According to reports from the two observatories mentioned above, most remarkable changes have taken place in the nebulosity during the last few weeks.

The Lick Observatory reports a southeasterly motion of the nebula amounting to one minute of arc in six weeks. If we assume that the nebula is at the distance of a star, the parallax of which is 0".25, then the velocity of the nebula in a direction perpendicular to the line of sight amounts to the astounding amount of 7,000 miles per second. The body cannot belong to the solar system, for at the time of the year that these photographs were taken its motion should have been retrograde — westerly instead of easterly.

Theories.— In a note to an article, "The Light-Curve of *Nova Persei*," printed in number 79 of these *Publications*, I suggested a modification of the tide theory as a possible explanation of the phenomena connected with this star. The spectroscopic observations of VON GOTHARD are easily explained under this theory. As the disturbing body approaches, the enshrouding vapor could be pulled to one side, which would give a maximum of light and a strong continuous spectrum. As the vapors moved into the line of sight of the observer a minimum of brightness would result and the continuous spectrum would be largely reduced, and the bright-line spectrum of the incandescent vapors would form the most prominent feature.

It is impossible to state just what the tidal effects upon the vapors would be; but if we assume that the effect would be very small, the observed phenomena could still be explained under this theory if the height of the wave in the liquid were comparable with the depth of the denser enshrouding vapors. Under such conditions the maximum would be sharp and well defined, while the minimum would be longer and poorly defined. The plotted light-curves show a decided tendency of this nature. This theory is in its main features the same as that suggested by Dr. HUGGINS several years ago. I had expected ere this to subject the theory to a more rigid analysis, but a pressure of other duties has prevented me from doing so. I hope soon, though, to discuss more critically several of the more important theories that have been advanced for the explanation of temporary stars. The most obvious objection to the one mentioned above is that it does not satisfactorily explain the change of the spectrum to that of a planetary nebula. The presence of a nebula about the star would seem to give strength to SEELIGER's theory.

Professor T. C. CHAMBERLIN, of the University of Chicago, published in the July number of the *Astrophysical Journal*, under the title "On a Possible Function of Diruptive Approach in the Formation of Meteorites, Comets, and Nebulæ," some interesting investigations along lines similar to those discussed above.

S. D. T.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, NOVEMBER 30, 1901, AT 7:30 P.M.

Mr. Dolbeer presided. A quorum was present. The minutes of the last meeting were approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED NOVEMBER 30, 1901.

Mrs. Addie L. Ballou	Room 62, 1170 Market Street, S. F., Cal.
Field Memorial Observatory	Williams College, Williamstown, Mass.
Prof. Chas. S. Howe	Case Observatory, Cleveland, Ohio.
Prof. Edgar L. Larkin	Director Mount Lowe Observatory, Echo Mountain, Cal.
Mr. Carl Ramus	Ass't Surgeon U. S. M. H. S., Fort Stanton, New Mex.
Prof. H. C Tillman	University of the Pacific, San José, Cal.

Mr. Stróvberg was elected to life membership.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, NOVEMBER 30, 1901, AT 8 O'CLOCK P. M.

President Dolbeer presided. The minutes of the last meeting were approved.

The Secretary read the names of new members elected at the Directors' meeting.

The following papers were presented:—

1. The Lick Observatory-Crocker Expedition to observe the Total Solar Eclipse of May 17-18, 1901. } Lecture by C. D. Perrine.
2. Motion in the Nebula surrounding *Nova Persei*. }
3. The U. S. Naval Observatory Eclipse Expedition to Sumatra, by H. D. Curtis.
4. Planetary Phenomena for January and February, 1902, by Malcolm McNeill.
5. Observations of the Variable Stars *W Lyræ* and *U3 Cygni*, by Rose O'Halloran.

Mr. Perrine's lecture, illustrated by lantern-slides, was given in the lecture hall of the Academy of Sciences on Friday evening, November 29th.

OFFICERS OF THE SOCIETY.

Mr. John Dolbeer	*President*
Mr. S. D. Townley	*First Vice-President*
Miss R. O'Halloran	*Second Vice-President*
Mr. Chas. S. Cushing	*Third Vice-President*
Mr. C. D. Perrine Mr. F. R. Ziel	*Secretaries*
Mr. F. R. Ziel	*Treasurer*

Board of Directors—Messrs. Babcock, Campbell, Cushing, Dolbeer, Hill, Molera, Miss O'Halloran, Messrs. Perrine, Pierson, Townley, Ziel.

Finance Committee—Messrs. Pierson, Hill, Cushing.

Committee on Publication—Messrs. Aitken, Townley, Galloway.

Library Committee—Mr. Townley, Miss O'Halloran, Miss Hobe.

Committee on the Comet-Medal—Messrs. Campbell (*ex-officio*), Pierson, Burckhalter.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Francisco Rodriguez Rey.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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(February, April, June, August, October, December.)

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Rome, Italy, Observatory of the Roman College.
Rome, Italy, Specula Vaticana.
San Francisco, California, California Academy of Sciences.
San Francisco, California, Technical Society of the Pacific Coast.

Stockholm, Sweden, University Observatory.
Strassburg, Germany, University Observatory.
Sydney, New South Wales, Observatory.
Tacubaya, Mexico, National Observatory.
Tokio, Japan, University Observatory.
Toronto, Canada, Astronomical and Physical Society of Toronto.
Toulouse, France, Observatory.
Turin, Italy, Observatory.
University Park, Colorado, Chamberlin Observatory.
University of Virginia, Virginia, McCormick Observatory.
Upsala, Sweden, University Observatory.
Vienna, Austria, Imperial Observatory.
Vienna (Ottakring), Austria, Von Kuffner's Observatory.
Washington, District of Columbia, Library of Congress.
Washington, District of Columbia, National Academy of Sciences.
Washington, District of Columbia, Naval Observatory.
Washington, District of Columbia, Smithsonian Institution.
Washington, District of Columbia, The American Ephemeris.
Washington, District of Columbia, U. S. Coast and Geodetic Survey.
William's Bay, Wisconsin, Yerkes Observatory.
Zurich, Switzerland, Observatory.

EXCHANGES.

Astrophysical Journal, William's Bay, Wisconsin.
Sirius, Cologne, Germany.
The Observatory, Greenwich, England.

FOR REVIEW.

[See *Publications*, A. S. P., vol. VIII, p. 101.]

The Call, San Francisco, California.
The Chronicle, San Francisco, California.
The Examiner, San Francisco, California.
The Mercury, San José, California.
The Record-Union, Sacramento, California.
The Times, Los Angeles, California.
The Tribune, Oakland, California.

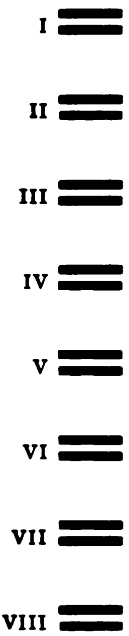
A METHOD FOR DETERMINING THE SCREW-ERRORS OF A ZENITH-TELESCOPE.

By Frank Schlesinger.

The zenith-telescopes in use at the four principal stations of the International Geodetic Association for Observing Variations in Latitudes are each accompanied by a double meridian-mark. By means of these, the adjustment of the azimuth-stops becomes a very simple matter and may be effected every night if necessary. In order to focus upon the marks, an auxiliary lens has been placed between the objective and ocular, and as near the latter as possible. This lens can be shunted into the optical axis whenever the meridian-marks are to be viewed; at other times it rests well to one side of the axis. This arrangement has suggested a method for examining the micrometer-screw, which has been tried at Ukiah with satisfactory results.

In the present case the meridian-marks are 55.5 meters (182 feet) north of the telescope; upon the small structure which serves to shelter them was fastened a vertical scale divided into seven nearly equal spaces. Each of these spaces was of such a length as to correspond approximately to one revolution of the micrometer-screw when the auxiliary lens was in position. The total length of the scale was actually 130^{mm}, each space being about 18.5^{mm}. It is not necessary in the method to be described that the scale be accurately divided. It was found that an entirely adequate scale could be ruled on drawing-paper with india-ink, like the one shown in the accompanying sketch. The division-marks were made double, and could be nicely bisected by the single thread of the micrometer. The screw has an effective length of twenty-eight revolutions. As it would be impractical to examine the whole screw at once, it was divided into four equal portions, and each of these was investigated separately. The method used to do this is an adaptation of that developed by GILL, LORENTZEN, and others. A clear account of this method is given by Professor HAROLD JACOBY in the *American Journal of Science* for May, 1896.

The micrometer having been set at about $1^{R}.0$, the telescope was pointed so that the micrometer thread coincided as nearly as possible with Division VII of the scale. Readings were made



upon this division, and also upon Division VIII, care being taken not to move the telescope between the two sets. The micrometer having been set back to $1^R.0$, the telescope was pointed at Division VI. Readings were then taken on Divisions VI, VII, and VIII. In this way the operations were continued until each space of the scale had been measured with each turn of the micrometer from $1^R.0$ to $8^R.0$. These measures furnish data from which the errors of both screw and scale can easily be computed. The three other parts of the screw were treated in an entirely similar manner; so that it only remained to determine the errors at 8^R, 15^R, and 22^R. This was done by measuring the total length of the scale with the four parts of the screw in succession. Throughout the work all operations were immediately repeated in reverse order, to provide as far as possible against changes in the telescope, in the observer, or in the scale.

Such an investigation as has been described was made at Ukiah and repeated until at least four determinations of each screw-error had been obtained. A comparison of the separate results gives only $0''.025$ for the probable error of a single determination. I give below a list of the definitive corrections. It will be noticed that they are small and that they run very smoothly, there being no abrupt change except at the extreme end of the screw. The units are hundredths of a second:—

R.	Corr.	R.	Corr.	R.	Corr.	R.	Corr.
1 ...	−1	8 ...	+4	15 ...	+2	22 ...	+3
2 ...	0	9 ...	+4	16 ...	−2	23 ...	−3
3 ...	−5	10 ...	+5	17 ...	−1	24 ...	−4
4 ...	−4	11 ...	+5	18 ...	−2	25 ...	−8
5 ...	−4	12 ...	+4	19 ...	−2	26 ...	−8
6 ...	−3	13 ...	+2	20 ...	−2	27 ...	−5
7 ...	+1	14 ...	+2	21 ...	+2	28 ...	+4
						29 ...	+12

If it be desired to use this method for determining the periodic as well as the progressive errors, a scale should be used whose total length corresponds to one turn of the screw and which is divided into four or five equal parts.

The auxiliary lens is not strictly necessary, as the vertical scale may be brought into focus by drawing out the ocular. In this case, however, it is not advisable to examine the screw concurrently with the latitude-observations, as the constants of the instrument are liable to disturbance.

The method which has been almost exclusively employed for determining the screw-errors of a zenith-telescope is that afforded by elongations of close circumpolar stars. The weak point in this method is the dependence upon the latitude-levels. A complete elongation of *Polaris* or of λ *Ursæ Minoris* occupies more than an hour for a telescope with a field of twenty minutes of arc. Latitude-levels, even under favorable circumstances, cannot be depended upon to maintain a constant angle with the telescope for so long a time. Moreover, during an elongation the observer must remain at one end of the levels — just the position in which the heat from his body is likely to warp them. It is this circumstance probably, to which are due the inaccurate results sometimes obtained by the method of elongations.

In his "Anleitung zum Gebrauche des Zenitteleskops" (Berlin, 1899), Doctor ALBRECHT has recommended the use of an auxiliary micrometer, to be fixed at the eye-end of the telescope. The errors of both screws can thus be determined simultaneously. In this method the optical system during the examination of the screw is entirely different from that used for the latitude observations, and slight systematic errors may creep in. This objection also applies, but in a lesser degree, to the method of this paper. The latter has the additional advantages of greater convenience and in requiring practically no auxiliary apparatus.

INTERNATIONAL LATITUDE OBSERVATORY,
Ukiah, California, 19 November, 1901.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1902.

By MALCOLM MCNEILL.

MARCH.

The Sun crosses the equator from south to north on March 21st, 5 A.M., Pacific standard time.

Mercury is a morning star, and comes to greatest west elongation on March 17th. Although its distance from the Sun at this time is 28° nearly, 10° more than it was at the east elongation in February, the planet is so far south of the Sun that the conditions for visibility are not very good. However, for the first twenty days of the month it rises about an hour before sunrise, and may be seen, if the weather conditions are exceptionally good, in the morning twilight.

Venus passed inferior conjunction on February 14th, and moves rapidly away from the Sun, so that by March 1st it rises about an hour and a half before sunrise. It ceases to move westward among the stars, and begins its longer eastward motion on March 6th; so its rate of recession from the Sun diminishes rapidly. At the end of the month it rises about two hours before sunrise. It will be very bright throughout the month, and will be at maximum brilliancy on March 21st. At this time it is about half-way between inferior conjunction and greatest elongation.

Mars is very near the Sun throughout the month, and on March 29th is in superior conjunction, becoming a morning star. Owing to the eccentricity of its orbit, this time of conjunction does not coincide with the time of maximum distance from the Earth. This does not occur until the latter part of May. The planet is about at its faintest, and will not brighten up much for several months.

Jupiter is getting far enough west of the Sun to be seen in the morning twilight. Its time of rising on March 1st is about the same as that of *Venus*, but it is considerably farther south. It moves about 6° eastward in the constellation *Capricorn.*

Saturn rises nearly an hour before *Jupiter*, and its distance from the latter increases from 11° to 15° during the month. It moves about 2° eastward in the region between *Sagittarius* and *Capricorn.*

Uranus rises not long after midnight. It is in the lower extension of *Ophiuchus*, between *Scorpio* and *Sagittarius.*

Neptune is in the extreme western part of *Gemini*, and is above the horizon until after midnight.

APRIL.

There will be two eclipses during April, neither of them visible in the United States.

The first is a partial eclipse of the Sun on April 8th, visible only in the northern parts of America and Asia. The maximum obscuration of the Sun will be only .06 of its diameter.

The second is a total eclipse of the Moon on April 22d, not visible in the western hemisphere.

Mercury is a morning star until April 28th. It then passes superior conjunction, and becomes an evening star, but throughout the month remains too near the Sun to be seen with the naked eye.

Venus is still the most conspicuous object in the morning sky. It rises about two hours before the Sun throughout the month. It comes to its greatest west elongation, 46°, on April 25th. The interval between rising of the Sun and planet is much shorter than it usually is at time of greatest elongation, on account of the fact that *Venus* is far south of the Sun at the time.

Mars is entirely too near the Sun and too faint to be seen during April. It is in the morning sky, but by the end of the month it is only 6° west of the Sun, and rises less than twenty minutes earlier.

Jupiter by the end of April rises at about half after one o'clock, and is therefore in a position for easy observation for early risers. It moves about 4° eastward in the constellation *Capricorn*.

Saturn rises about an hour before *Jupiter*. It is in the western part of *Capricorn* and is still moving eastward, but with a much slower motion than that of *Jupiter*, only 1° during the month.

Uranus keeps about the same place. It ceases its eastward motion during March, and is now slowly moving westward.

Neptune remains in the western part of *Gemini*.

MARCH–APRIL, 1902.

PHASES OF THE MOON, P. S. T.

Last Quarter . . .	Mar.	2,	2^h	39^m	A. M.
New Moon . . .	Mar.	9,	6	50	P. M.
First Quarter . . .	Mar.	16,	2	13	
Full Moon . . .	Mar.	23,	7	21	
Last Quarter . . .	Mar.	31,	10	24	
New Moon . . .	Apr.	8,	5	50	A. M.
First Quarter . . .	Apr.	14,	9	26	P. M.
Full Moon . . .	Apr.	22,	10	50	A. M.
Last Quarter . . .	Apr.	30,	2	58	P. M.

THE SUN.

1902.		R. A.	Declination.	Rises.	Transits.	Sets.
Mar.	1,	$22^h\ 46^m$	— 7° 49′	$6^h\ 39^m$ A.M.	$12^h\ 13^m$ P.M.	$5^h\ 47^m$ P.M.
	11,	23 23	— 3 58	6 23	12 10	5 57
	21,	0 0	— 0 1	6 8	12 8	6 8
	31,	0 36	+ 3 54	5 51	12 4	6 17
Apr.	10,	1 13	+ 7 42	5 36	12 2	6 28
	20,	1 50	+ 11 17	5 20	11 59 A. M.	6 38
	30,	2 27	+ 14 34	5 7	11 57	6 47

MERCURY.

Mar.	1,	21 30	— 12 24	5 39 A.M.	10 56 A.M.	4 13 P.M.
	11,	21 42	— 13 40	5 15	10 28	3 41
	21,	22 21	— 11 57	5 9	10 28	3 47
	31,	23 11	— 7 45	5 6	10 40	4 14
Apr.	10,	0 10	— 1 30	5 4	10 59	4 54
	20,	1 17	+ 6 25	5 5	11 26	5 47
	30,	2 34	+ 15 6	5 12	12 4 P.M.	6 56

VENUS.

Mar.	1,	21 13	— 7 45	5 6 A.M.	10 40 A.M.	4 14 P.M.
	11,	21 13	— 9 18	4 32	10 0	3 28
	21,	21 27	— 9 59	4 9	9 35	3 1
	31,	21 52	— 9 38	3 53	9 20	2 47
Apr.	10,	22 23	— 8 18	3 40	9 12	2 44
	20,	22 58	— 6 8	3 28	9 8	2 48
	30,	23 35	— 3 15	3 14	9 5	2 56

MARS.

Mar.	1,	23 11	— 6 18	6 18 A.M.	12 37 P.M.	6 16 P.M.
	11,	23 39	— 3 10	6 36	12 26	6 16
	21,	0 8	— 0 0	6 15	12 15	6 15
	31,	0 36	+ 3 9	5 54	12 4	6 14
Apr.	10,	1 4	+ 6 12	5 33	11 53 A.M.	6 13
	20,	1 33	+ 9 8	5 13	11 42	6 13
	30,	2 1	+ 11 54	4 50	11 31	6 12

JUPITER.

Mar.	1,	20 30	— 19 22	5 6 A.M.	9 57 A.M.	2 48 P.M.
Apr.	1,	20 55	— 17 53	3 35	8 20	1 5
May	1,	21 12	— 16 46	1 37	6 39	11 41 A.M.

SATURN.

Mar.	1,	19 45	— 21 9	4 27 A.M.	9 12 A.M.	1 57 P.M.
Apr.	1,	19 55	— 20 45	2 34	7 20	12 6
May	1,	19 59	— 20 35	12 39	5 26	10 13 A.M.

URANUS.

Mar.	1,	17 21	— 23 12	2 12 A.M.	6 48 A.M.	11 24 A.M.
Apr.	1,	17 22	— 23 13	12 11	4 47	9 23
May	1,	17 20	— 23 12	10 7 P.M.	2 43	7 19

NEPTUNE.

Mar.	1,	5 54	+ 22 17	noon.	7 20 P.M.	2 40 A.M.
Apr.	1,	5 55	+ 22 18	9 58 A.M.	5 18	12 38
May	1,	5 57	+ 22 20	8 3	3 23	10 43 P.M.

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope.)

I, D,	Mar. 6,	6^h 19^m A.M.	IV, R,	April 1,	3^h 31^m A.M.
II, D,	12,	3 21	II, D,	6,	12 22
I, D,	15,	2 42	I, D,	7,	2 52
IV, D,	15,	5 9	I, D,	13,	2 50
II, D,	19,	5 56	I, D,	14,	4 46
I, D,	22,	4 36	III, R,	20,	12 51
III, D,	22,	5 26	II, D,	20,	5 30
I, D,	31,	12 58	I, D,	23,	1 8
			III, D,	27,	2 23
			III, R,	27,	4 51
			I, D,	30,	3 2

HUSSEY'S MEASURES OF THE OΣ DOUBLE STARS.*

By S. W. Burnham.

One of the most important and interesting contributions of practical astronomical work has just been issued by the great Observatory at Mt. Hamilton, as Volume V of the *Publications of the Lick Observatory*. This quarto volume of 227 pages contains the reobservation and measurement by Professor HUSSEY of all the double stars of the first edition of the Poulkowa Catalogue of 1843. Each of the pairs has been measured on an average of three nights with either the 12-inch or the 36-inch refractor, the most difficult of these objects, of course, being observed with the large instrument. The measures were made principally from 1897 to 1900, and, for the most part, all the measures of each star were made in the same year. It is well known that in the second edition of 1850 of the Poulkowa Catalogue many of the stars of the first catalogue were rejected,—some because the suspected elongation was not confirmed by subsequent examinations, some because the companion-star was too distant, and some because they had been found to be identical with previously known pairs in the catalogues of W. STRUVE, HERSCHEL, and others. These rejected numbers amount altogether to 106 stars. The original number of the OΣ stars was 514, but other new pairs were found from time to time, and the total number was finally extended to 547.

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*Reprinted from *Popular Astronomy* for December, 1901.

HUSSEY has accounted for all these stars, rejected and otherwise, and arranged them in this general catalogue in numerical order, with a table at the end of the volume giving them in order of Right Ascension with positions for 1900, so that any star can be found by its number or place. He has collected with remarkable thoroughness substantially all the published measures of each pair, and placed them in chronological order, with a reference to the place of publication. One can see at a glance whether or not there is any relative motion, and generally what the change is in the last sixty years, where there is change in the components from proper or orbital motion. The notes accompanying each star are complete, and give all that is worth mentioning concerning the character and history of the pair. They are models of completeness for brevity. When necessary they are illustrated by diagrams showing the relative change in the components.

The pairs rejected as single have all been carefully examined with the great telescope, and in each instance no elongation detected under favorable conditions. Many of these stars had been previously examined by the writer with the same telescope and with Chicago 18½-inch with the same result, but it is always possible that a star of this class may be really double, though so close from the rapid motion of the components that at a given time it is single with the largest aperture. As many of these stars have been watched more or less at intervals in the last thirty years, without showing any signs of duplicity, in first-class refractors, it is safe to say that in all probability the orginal observations which led to their being placed in the Poulkowa Catalogue was a mistake, and the supposed elongation not real.

Of the other class of wide pairs, although not likely to be of any interest as physical double stars, many of them were in need of measurement, as some depended upon perhaps a single observation of MADLER made more than half a century ago. Some of them were placed on the working list of neglected pairs prepared by the writer for observation at the Yerkes Observatory, not knowing at that time that HUSSEY'S plan embraced all these stars. My work in this direction was, of course, discontinued after receiving this volume, as there would be no excuse for duplicating work already so carefully and well done.

In the course of these observations Professor HUSSEY found new components to five of the Poulkowa stars, and two of these, OΣ 351 and OΣ 476, seem to be remarkable objects visually, and likely to be remarkable hereafter as physical systems. The known components of the first pair are only 0".6 apart, while one of them is composed of two stars, with a distance of only 0".3. In the other case the OΣ components have a distance of 0".54, and the smaller of these is a close pair, with a distance of 0".15. These are the closest triple stars known, and are certain to be interesting physical systems, and perhaps in rapid motion. Discoveries of this kind must necessarily be made with large refractors, and while it is possible that these stars are more readily seen now than heretofore, it is certain that they are beyond the grasp of all, or nearly all, the instruments used for the measurement of these stars in former years.

The Director of Lick Observatory and the authorities of the University of California have earned the thanks of the astronomical world for the prompt publication of this beautiful volume. The printer's work has been so well done that it may be said to represent the highest art in this class of composition. The arrangement of the matter and the selection of the various kinds of type make a volume both convenient and pleasant to use. The plan generally is that adopted in the General Catalogue of the β stars, issued as Volume I of the *Publications of the Yerkes Observatory.*

This volume will practically take the place of all former works relating to this subject-matter, since it contains all that is needed in the earlier catalogues and publications. It should prevent hereafter much waste of time in duplicating measures, and observing pairs for which no measures, for many years, are needed. The stars which are shown to be relatively fixed, or where the change is slow, will need no further attention for at least a quarter of a century. On the other hand, those in rapid orbital motion should be measured by one of the large telescopes at short intervals, some of them every year. For some of these binaries new orbits have been computed, based upon the new and later measures. Among others is an orbit of δ *Equulei*, from which it appears that a period of 5.7 years will satisfy the measures as well or better than the 11.4-year period heretofore supposed to be the true time. Should this shorter period prove to be correct — and the prima facie case made seems to be a strong one — it will be the most rapid binary now known. If this pair is carefully watched and measured several times each year when the apparent motion is most rapid, as it doubtless will be at Mt. Hamilton, it will not require long to determine which of the periods is correct. It is fortunate that micrometrical work, and especially that relating to double stars, is in the hands of two such zealous and expert observers as HUSSEY and AITKEN.

One can imagine the pleasure with which the venerable OTTO STRUVE will examine this work, which brings together for the first time in a perfect and permanent form his great discoveries of more than half a century ago. At this time in his life, when his work with the telescope has been concluded, he cannot fail to appreciate the value of this volume as a permanent monument to his memory.

NOTICES FROM THE LICK OBSERVATORY.*

Prepared by Members of the Staff.

Further Observations of the Nebula about *Nova Persei.*

Since the photograph of November 7–8th, five other negatives have been secured with the Crossley reflector, as follows:— November 12–13th, December 4th, December 8th and 11th, January 2–3d and January 10–11th. With the exception of that of December 4th, all have had exposures of ten hours. These later photographs have been obtained on quicker plates, and with the longer exposures, much more detail is shown than on the first.

These negatives show two distinct regions of nebulosity to exist about the *Nova*. The region about the star within a radius of 7′ is filled with nebulosity showing much detail. It is in this region where the condensations are situated which were first observed to be in rapid motion. Outside of this circular region of 15′ diameter is a ring of very much fainter nebulosity, having an extreme diameter of 30′. This nebulosity is so faint, in fact, that, with the exception of a few of the brighter wisps, it is not visible until intensified by successive copyings on slow plates. This method of bringing out faint contrasts is one well known to experienced photographers and has long been in use at this Observatory.

The motions which were observed in some of the brighter condensations are shown by the later photographs to continue. These motions are not radial, although the entire circle of nebula is expanding. Some of the observed motions are clockwise, while others appear to be moving in the opposite direction.

With the exception of two groups of filaments in the faint outer ring of nebulosity, there is not sufficient structure there for a satisfactory determination of motions. Of the two masses mentioned, one shows a clockwise motion and the other a counter-clockwise motion of about 3′ in the interval of a month between the December and January observations. The larger proportion of motion is tangential, the radial component amounting to nearly 1′. Neither of these two groups of nebulosities was visible on the photograph of November 7–8th. One of them shows very faintly on the negative of November 12–13th, the other on a negative with only 5½ hours' exposure on December 4th. The later negatives all show both groups. Some exceedingly fine structural detail is also shown on the later negatives in the extreme outer portion of this outer ring, to the west of *Nova*. This detail is composed of the finest threadlike filaments, and in this also can be traced a general outward movement.

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* Lick Astronomical Department of the University of California.

In examining the earlier short-exposure negatives of the *Nova* for another purpose, I found one, taken on March 29th with an exposure of ten minutes, which shows a complete ring of faint nebulosity about the *Nova*. These photographs were obtained by Messrs. H. K. PALMER and C. G. DALL while the writer was absent on the Eclipse Expedition to Sumatra.

This photograph carries back our knowledge of the nebula nearly five months. The earliest observations previously known were by Professor MAX WOLF, on August 23d, and Mr. RITCHEY, of the Yerkes Observatory, on September 20th.

The ring of nebulosity shown on the negative of March 29th is not perfectly circular, but is flattened on the southwest side. The longer axis of the oval is in the direction southeast-northwest, and is about 5′ in length. The ring is approximately 20″ in width in the best-defined portions. The nebulosity at the ends of this oval is much more diffuse and broadened and resembles somewhat the Annular Nebula in *Lyra*. Inside this ring and very close around the star is an elliptical ring of much fainter nebulosity whose major axis is in position-angle 60°. The *Nova* occupies the southwest focus of this ellipse, whose major axis is 2½′ in length and its minor axis 2′.

A narrow circular arc of nebulosity extends from position-angle 0° to 90° at a distance of 5′ from *Nova*, which occupies the center of curvature.

Besides the features described, there is a series of faint envelopes to the south of the star, at a distance of 3′, which has an arrow-shaped form pointing to the east. There are also some faint masses of nebulosity to be seen inside the larger ring. As the later observations showed the outer ring of nebulosity to be expanding at about the rate which would have carried the ring of March 29th to its present position, the assumption of probable identity was made and the velocity of recession radially from the star determined. This was possible from two well-defined masses on the outer rim of the large exterior nebulosity, using the interval March 29, 1901, to January 2–3, 1902. One of these masses was southwest of *Nova*, the other north. The mass to the southwest gave a velocity of 3″.00 per day; the mass to the north gave a velocity of 2″.62 per day. These velocities carry their respective nebulosities (both rings) back to the *Nova* on February 17th and 16th. Each pair of results agrees within a small fraction of a day, which must be considered largely accidental owing to the uncertainties of measuring such objects. Many of the condensations are growing fainter, owing, probably, to the general expansion. Condensation A was very compact when first observed on November 7–8th. It has now separated into three envelopes, the whole being much fainter. Several new masses have appeared in its vicinity. Condensation D seems to have remained unchanged either in intensity or form, since November 7–8th.

We may summarize briefly the results of a comparison of all our negatives, as follows:—

Great changes are still going on in the nebulosity about the *Nova*. Some masses appear to be growing brighter, while others are growing fainter.

The nebulosity is found chiefly in two regions. The brighter is situated in a circular area 15′ in diameter, in which *Nova* occupies the center. Around this region is a ring of much fainter nebulosity 30′ in diameter. Both of these regions are expanding rapidly in all directions. Many portions of the nebula are in rapid motion. Several of the condensations appear to have a spiral motion, some clockwise, others the reverse. No entirely radial motion has been observed. The nebulosity now visible appears to have been expelled from the region of the star about February 16th or 17th (neglecting light transmission) in the general form of rings or shells.

If this nebulosity is moving in all directions at its present rate of speed, and should continue at this rate, some of it should reach the solar system in 250 years or less.

Messrs. H. K. PALMER and JOEL STEBBINS, Fellows in Astronomy, have assisted in taking the later photographs with the Crossley reflector. C. D. PERRINE.

MT. HAMILTON, CALIFORNIA, 1902, January 15.

OBSERVATIONS OF 194 DOUBLE STARS.

My double-star observing-list for the years 1900 and 1901 was made up largely of the more rapid binaries and other difficult pairs taken principally from the catalogues of BURNHAM, HOUGH, and the CLARKS.

About six hundred measures of one hundred and ninety of these stars, besides notes on four that were found to be single, have been published as Bulletin No. 11 of the Lick Observatory. Of the measured pairs, ninety-four have distances of 0″.5 or less, including some of the closest pairs known; forty-two more have distances ranging from 0″.5 to 1″.0, and, of the wider pairs, many are difficult, by reason of the faintness of the smaller star. The great majority of the measures were made with the 36-inch telescope.

The double-star system that is of greatest interest at present is δ *Equulei* = OΣ 535. My observations of this pair made in 1900 were printed in No. 76 of these *Publications*, and the first two secured in 1901, in No. 79. In May, June, and July measures were made without special difficulty, the angular separation of the components reaching a maximum of about 0″.15.

During September and October the apparent distance between the two components again began to grow smaller and measures became more difficult. The star was followed carefully as long as it was in reach, the last observation being made on December 19th. On that date, the highest power eye-piece for the 36-inch telescope showed no certain elongation. The seeing was very good. These observations, confirmed as they are by those made by Professor HUSSEY, seem to present conclusive evidence in favor of the 5.7-year period of revolution. It is certain that the companion moved out to elongation and in again in little more than a year's time.

R. G. AITKEN.

January 15, 1902.

DUPLICITY OF THE PRINCIPAL COMPONENT OF Σ 238.

A recent examination of this pair with the 36-inch telescope revealed the existence of a close companion to the brighter star. The mean of three nights' measures is:—

1902.00 108°.1 0″.85 8.3 - 10.7

My measure of the Struve pair is —

1901.970 356°.9 10″.83 1n

which agrees almost exactly with STRUVE's measure made in 1830, showing that the wide pair is fixed.

R. G. AITKEN.

January 15, 1902.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

Mr. JOHN A. BRASHEAR, the well-known optician, has been elected Chancelor of the University of Western Pennsylvania.

CHARLES A. BACON, professor of astronomy in Beloit College, Wisconsin, and director of Smith Observatory, died November 6, 1901.

The report of the Board of Visitors of the United States Naval Observatory has been published in *Science*, December 6th. Extracts from the report of the Superintendent of the Naval Observatory, with some editorial comments, are printed in the issue of the same journal for December 20th.

At the meeting of the Astronomical and Astrophysical Society of America held in Washington, D. C., December 30, 1901, to January 3, 1902, the following officers were elected: President, SIMON NEWCOMB; First Vice-President, G. E. HALE; Second Vice-President, W. W. CAMPBELL; Treasurer, C. L. DOOLITTLE; Councilor, E. C. PICKERING; Councilor, R. S. WOODWARD.

The next meeting of the Society will be held at Washington, in December, 1902.

At a meeting of the National Academy of Sciences at Washington in April, Professor S. P. LANGLEY read a paper reviewing his work in the investigation of the solar spectrum, the paper being a summary of the results embodied in Volume I of the *Annals of the Astrophysical Observatory of the Smithsonian Institution*. As illustrating the principal feature of the work, a map was shown of the solar spectrum, only a small part of which, on the left, was the visible spectrum known to Sir ISAAC NEWTON. This was the familiar colored spectrum. The remainder consisted of the extended range of the solar energy invisible to the eye, but which by the researches of Professor LANGLEY was now mapped with the variations of energy shown by curves.

The visible spectrum, from a little beyond the violet, at a wave-length of somewhat less than $0.4\,\mu$, down to the extreme red, which is considered to terminate at the almost invisible line A, whose wave-lenghth is $0.7\,\mu$, has been the seat of prolonged spectroscopic investigation. On a scale of the actual wave-length of light, where the unit of measurement (1μ) is one one-thousandth of a millimeter, the length of the visible spectrum is 0.36μ. This prominence of the visible spectrum is due partly to the reason that it is visible, and partly to the fact that the ordinary prism gives an immensely extended linear depiction of the really small amount of energy in this visible part. The region beyond the violet has also received undue attention from the fact that the salts of silver used in photography are extremely sensitive to the short wave-length rays of this portion, although this portion is lacking in energy.

On the map shown, a scale had to be adopted for the spectrum, which has really no positive dimension, being extended at one end or the other, according to the use of the prism or grating employed in producing it. The scale used was such that the infra-red portion of the spectrum, as given by a rock-salt prism, was correct. The visible and ultra-violet given was not exact; for on the prismatic scale it would have taken nearly 100 feet of map to depict, although the ultra-violet really contains much less than one one-hundreth part of the total solar energy, and the visible spectrum but about one fifth. The only law which governs is that the amount of energy in any region of the spectrum, such as that in any color, or between any two specified limits, is a definite quantity fixed by facts independent of our choice, such as the nature of the radiant body or the absorption which the ray has undergone.

Everything in linear presentation, then, depends on the scale adopted. If the lengths be proportional to the energies, the familiar prismatic representation enormously exaggerates the importance of the visible and still more of the ultra-violet region, and similarly the grating spectrum exaggerates that of the infra-red region. On the adopted scale, the visible spectrum had been drawn on the average dispersion of the infra-red.

Of the invisible region beyond the infra-red, nothing was known until 1800, when Sir WILLIAM HERSCHEL found heat there with a thermometer, although this region contains four fifths of the solar energy. Sir JOHN HERSCHEL determined that the heat was not continuous; but it was not until 1871, when LEMANSKY made a drawing of the energy-curve (which, being without scale, is indeterminate), that much was known regarding this region. Three depressions are shown in his curve, indicating lapses of heat in the infra-red. They probably indicate something near to a wave-length of 1 μ. It was this drawing that first interested Professor LANGLEY in the subject.

Prior to 1885 the true wave-lengths were imperfectly known, but were then determined by Professor LANGLEY as far as the end of what he has called the "New Spectrum," at a wave-length of 5.3 μ. After this the next important addition to the subject was made by Captain ABNEY, who gave the photographic spectrum down to 1.1 μ.

The predecessors of Professor LANGLEY had worked with the thermopile, which was insufficient in the feeble heat of the grating-spectrum for good results. This led to his invention of the bolometer, about 1880. The basic idea in this instrument is the formation of a Wheatstone bridge. The variation in conductivity of one arm of the bridge, due to a variation in temperature, while the other arm of the bridge is of a constant temperature, can be measured by a galvanometer. As constructed, the two arms of the bridge are formed by two platinum tapes, one exposed to the heat and the other screened. The width of tape in some bolometers is one two-hundred-and-fiftieth of an inch and its thickness but one tenth of its width. With the improvements introduced in the attending galvanometer by Mr. ABBOTT, it is now possible to register changes in temperature of one one-hundred-millionth of a degree, with an error of less than two one-hundredths of one per cent.

With this sensitive instrument it is possible to locate the invisible lines with an accuracy equal to that of refined astronomical measurements. The action of the bolometer can be compared to an eye that sees in the dark. The solar energy is everywhere the same, and is "light" or "heat" only in accordance with the organ that interprets it. Hence lines like the dark Fraunhofer lines in the visible spectra appear to the bolometer as cold bands, and this hairlike strip of platinum is moved along in the invisible part of the spectrum till the galvanometer indicates the all but infinitesimal change of temperature caused by its contact with such a "cold band."

The first method of observation was extremely slow and tedious, as it required hundreds of observations by three persons to determine with appropriate accuracy the position in wave-length of one invisible line. It took two years to map about twenty such lines, and it was possible that a thousand lines existed.

After twelve years of experimenting, an automatic apparatus has been devised which registers in an hour the lines which would have taken half a century to register by the first method.

Briefly, the method is this: A great rock-salt prism (for a glass one would not transmit these lower rays, nor could they easily be detected in the overlapping spectra of the grating) is obtained of such purity and accuracy of figure, and so well sheltered from moisture, that its clearness and its indications compare favorably, even in the visible spectrum, with those of the most perfect prism of glass, with the additional advantage that it is permeable to the extreme infra-red rays in question. This prism rests on a large azimuth-circle turned by clockwork of the extremest precision, which causes the spectrum to move slowly along, and in one minute of time, for example, to move exactly one minute of arc of its length before the strip of the bolometer, bringing this successively in contact with one invisible line and another. Since what is blackness to the eye is cold to the bolometer, the contact of the black lines chills the strip and increases the electric current. The bolometer is connected by a cable with the galvanometer, whose consequent swing to the right or the left is photographically registered on a plate which the same clockwork causes to move synchronously and uniformly up and down by exactly one centimeter of space for the corresponding minute. By this means the energy-curve of an invisible region, which directly is wholly inaccessible to photography, is photographed upon the plate.

The number of lines in the infra-red spectrum is over seven hundred, and exceeds the number of visible ones in Kirchoff and Bunsen's charts.

In this way the spectrum of solar energy, which has been discovered by the French observers to extend to $1.8\,\mu$, and to which Dr. JOHN DRAPER had set, from theoretical considerations, a limit of a wave-length of $1\,\mu$, has now been discovered and mapped by Professor LANGLEY to a wave-length of $5.3\,\mu$. The region between $1.8\,\mu$ and $5.3\,\mu$ he has termed the "New Spectrum."

One result obtained by these investigations is that, under similar conditions as to altitude and atmosphere, the amount of solar energy varied with the season. Since all life on the Earth depends for its existence on the Sun's energy, it follows that by this means some record might be made of varying solar energy and predictions made of the character of the seasons, and a consequent benefit secured therefrom for humanity. J. D. G.

Continuing the plan inaugurated two years ago, letters were recently sent to the directors of the chief observatories of the Pacific Coast, asking for a statement of the work accomplished during 1901. From the answers received the following accounts have been written:—

CHABOT OBSERVATORY. — Mr. BURCKHALTER writes as follows:—

"In answer to the request of the Committee on Publication, I have very little to report of value in the way of original work for the past year. The observatory was given to the Board of Education of Oakland for popular instruction to the public and schools, etc., and, as the observavatory has always been exceedingly popular, the assistant in charge also being required to give a half-day to school-work, scarcely any time is left for original work. All my spare time the past year was taken up in supervising and devising certain parts of the new Assembly Hall just added to the observatory, for which I was held responsible"

INTERNATIONAL LATITUDE OBSERVATORY. — Dr. SCHLESINGER'S report of the work accomplished at this observatory is as follows:—

"The programme of the International Geodetic Association for Observing Variations of Latitude has been continued without modification at this station, as well as at the five others, throughout 1901. Below is given a summary of the observations made here during the year.

"I. *Observations for latitude proper.*— The following table gives the number of nights and the number of pairs observed in each month:—

1901.	January	14 nights	123 pairs.
	February	10 "	123 "
	March	18 "	153 "
	April	17 "	169 "
	May	17 "	167 "
	June	15 "	187 "
	July	14 "	170 "
	August	15 "	192 "
	September	13 "	146 "
	October	15 "	187 "
	November	12 "	135 "
	December	15 "	163 "
	Totals	175 nights	1,915 pairs.

"II. *Observations for the control of the position of the instrument.* —Owing to the admirable stability of the zenith-telescope and of the meridian-marks, these observations were made only once in about two months. No appreciable error in the latitude would have been incurred if such observations had been omitted altogether during the year.

"III. *Observations for values of the level-spaces.* — One series for this purpose was made during the summer.

"IV. *Observations for micrometer-value.* — The *Pleiades* were observed on every possible occasion during January. One elongation of *Polaris* was observed for the same purpose.

"V. *Observations for screw-errors.* — The *periodic* errors of the micrometer-screw are being examined by the same method as that used for the *progressive* errors. This method is described on other pages of this number.

"No definitive reduction of the observations at the six latitude stations has yet been published. A preliminary discussion including all observations up to January, 1901, will be found in the *Astronomische Nachrichten*, No. 3734."

LICK OBSERVATORY. — Owing to his absence in the East to attend the meeting of the Astronomical and Astrophysical Society of America, Director CAMPBELL finds it impossible to prepare a report for this number of the *Publications*.

MOUNT LOWE OBSERVATORY. — Professor EDGAR L. LARKIN'S account of the work accomplished at this observatory is as follows:—

"The writer assumed directorship of this observatory on January 1, 1901. The year has been one of confusion in building, painting, and putting in electric lights, so that extensive observations have not been made. A new science hall has been added to the building — mostly for spectroscopic and other optical work — and a new covering put on the dome.

OBSERVATIONS, 1901.

January 10th	GIACOBINI'S comet.
February 25th	The new star in *Perseus*.
May 17th and 18th . .	The Australian comet.
August 14th	ENCKE'S comet.
November 15th	The Leonid meteors — 661 recorded.
November 27th	Conjunction *Jupiter* and *Saturn*.
Since July	The sodium lines.
During the year . . .	The stellar floor.
The year	Standard thermometer, barometer, and rain-gauge.

"Since the Brashear spectroscope was mounted in its new room in July, a preliminary study has been made of the two sodium lines and adjacent regions. The heliostat was a home-made affair, bad beyond comparison. A new one of perfect workmanship is now on the way from BRASHEAR. The spectrum has been examined often at precise instants of sunrise, when the Sun's limb is rising over bare rock on the summits of the mountains, or emerging from thickets of manzanita shrubs; also

> at instants of sunset both in the sea and over rocks capping the coast ranges. No interpretation is offered. The dust question is looming up in spectroscopy; and the silicious sheets sent hither by the Mojave Desert make havoc with solar rays and quench their waves. Often eleven lines are seen between D_1 and D_2, from five to fifty between D_2 and D_3, and as many more on the opposite side of D_1 to an equal distance. These phenomena must be studied a year after the arrival of the new heliostat before anything of value is derived from the research, if at all. The spectrum of *Nova Persei* secured here on February 25th is well represented by figure 1, following page 232, No. 81, these *Publications*."

Mr. LARKIN has also interested himself in a study of the sky on dark clear nights. The mountain station has a particular advantage for such work as this, as the observer is usually far above the dust-laden atmosphere of the lower levels. Mr. LARKIN's report of the work is unfortunately too long to reproduce here, but the nature of the results obtained is indicated by the following sentence:—

> "The entire background of *Orion*, as seen here, is either a complete nebula or an incredible number of excessively minute stellar points. After a rain and on the clearest, darkest nights, *Orion* is always bound in white, while at the same time other portions of the celestial vault are jet black between the stars."

STUDENTS' OBSERVATORY.—The special announcement to students mentioned in the report of last year has been printed and distributed. It gives a description of the instrumental equipment of the Lick and Students' observatories and a comprehensive outline of the courses of study, both graduate and undergraduate, and special lines of work that the students may take up The student may specialize along one of three lines, the nature of which is sufficiently indicated by the names,—Theoretical Astronomy and Celestial Mechanics; Astrophysics; Geodesy. During the first term of 1901 the total enrollment of students in astronomical courses was 92, and during the second term 119. Several special lines of work were carried on during 1901. Professor LEUSCHNER'S work upon the orbit of the faint asteroid discovered by the late Professor KEELER with the Crossley reflector has led to a new method of determining orbits from three observations. The work is to be published in the Lick Observatory Bulletins under the title of "A Short and General Method of Determining Orbits from Three Observations." Professor LEUSCHNER and Miss HOBE have also published in this same connection "Elements of Asteroid 1900 G. A. and Ephemeris for the Opposition of 1901–1902." Both of these papers were presented in the recent meeting of the Astronomical and Astrophysical Society of America. The new method has been applied by Mr. R. A. CURTISS and Mr. C. G. DALL to Comet *c* 1900, and is now being tested by application to the South Comet 1901 by Mrs. L. S. RICHARDSON and Mr. C. A. G. WEYMOUTH. Dr. TOWNLEY has been studying the light variations of *Nova Persei*, and a portion of the results obtained has already been printed in these *Publications*. Mr. J. D. MADDRILL, assistant in the observatory, has observed the magnitudes of *Nova Persei* and micrometer positions of asteroids. Dr. A. F. GILLIHAN, a special student, has also made micrometer observations of asteroids. Dr. R. T. CRAWFORD and Dr. F. E. ROSS are engaged for the Watson Trustees in computing the general perturbations of the Watson asteroids.

UNITED STATES COAST AND GEODETIC SURVEY OBSERVATORY.—This observatory, situated in the Presidio Reservation, San Francisco, and provided with a transit and a zenith-telescope, is used as a longitude base for the determination of new stations by telegraphic time-signals and for practice of observers. Captain AUG. F. ROGERS, Assistant in Coast Survey, and in charge of the observatory, writes, however, that no new determinations were made during 1901.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, JANUARY 25, 1902, AT 7:30 P.M.

President **DOLBEER** presided. A quorum was present. The minutes of the last meeting were approved.

A committee to nominate a list of eleven Directors and Committee on Publication, to be voted for at the annual meeting, to be held on March 29th, was appointed as follows: Messrs. D. S. **RICHARDSON** (Chairman), C. **BURCKHALTER**, J. **COSTA**, GEO. L. **DILLMAN**, **HENRY J. CROCKER**.

A committee to audit the accounts of the Treasurer, and to report at the annual meeting in March, was appointed as follows: Messrs. **CHAS. S. CUSHING** (Chairman), F. H. **MCCONNELL**, O. **VON GELDERN**.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, JANUARY 25, 1902, AT 8 O'CLOCK P. M.

President **DOLBEER** presided. The minutes of the last meeting were approved.

The following papers were presented:—

1. A Method for Determining the Screw Errors of a Zenith-Telescope, by Dr. **FRANK SCHLESINGER**.
2. Planetary Phenoma for March and April, 1902, by Professor **MALCOLM MCNEILL**.

In lieu of a scientific programme for this evening, a Special Meeting of the Society was called, to be held in Hearst Hall at Berkeley on Febuary 21, 1902, at 8 o'clock P. M., in conjunction with the University Exhibit of Astronomical Photographs taken at the Lick Observatory. It was announced that Professor W. W. **CAMPBELL** would address the meeting, giving an account of the meeting of the American Astronomical and Astrophysical Society, recently held in Washington.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. John Dolbeer	*President*
Mr. S. D. Townley	*First Vice-President*
Miss R. O'Halloran	*Second Vice-President*
Mr. Chas. S. Cushing	*Third Vice-President*
Mr. C. D. Perrine Mr. F. R. Ziel	*Secretaries*
Mr. F. R. Ziel	*Treasurer*

Board of Directors—Messrs. Babcock, Campbell, Cushing, Dolbeer, Hill, Molera, Miss O'Halloran, Messrs. Perrine, Pierson, Townley, Ziel.

Finance Committee—Messrs. Pierson, Hill, Cushing.

Committee on Publication—Messrs. Aitken, Townley, Galloway.

Library Committee—Mr. Townley, Miss O'Halloran, Miss Hobe.

Committee on the Comet-Medal—Messrs. Campbell (*ex-officio*), Pierson, Burckhalter.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Francisco Rodriguez Rey.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

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OF THE
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VOL. XIV. SAN FRANCISCO, CALIFORNIA, APRIL 1, 1902. No. 83.

ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, IN AWARDING THE BRUCE MEDAL TO PROFESSOR G. V. SCHIAPARELLI.

By JOHN DOLBEER.*

The statutes for the bestowal of the Bruce Medal of the Astronomical Society of the Pacific direct that the President "in his address at the annual meeting of the Society in March is to announce the award and the reasons for making it." Complying with the statutes, I therefore take pleasure in announcing that by unanimous vote of the Board of Directors the Bruce Medal for the year 1902 was awarded to Professor GIOVANNI VIRGINIO SCHIAPARELLI, "for distinguished services to astronomy."

Every member of the Society will doubtless agree that no more worthy recipient of the medal could be found than Professor SCHIAPARELLI; and that it is especially appropriate that he should receive it at this time, when he has retired from the directorship of the observatory made famous throughout the world by his labors during the past forty years. For, unlike many, if not most, other medals founded to encourage astronomical work, the Bruce Medal is not bestowed as an award for some one particular research or discovery, however brilliant, but rather as the mark of our recognition of the fact that the medalist, by his long-continued and successful labors, has made himself one of the great leaders in the advance of the science of astronomy.

In the minds of most intelligent people outside of the ranks of the professional astronomers, the name of SCHIAPARELLI is probably most prominently associated with the planet *Mars;* and it is unquestionably true that his remarkable studies of the physical characteristics of that interesting planet form a strong claim to the high regard in which he is held by astronomers to-day. As one of our own members has said,—

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*I am indebted to Professor R. G. AITKEN, of the Lick Observatory, for the collection and arrangement of the data contained in this address.

> "Professor SCHIAPARELLI has fixed the principal points of the planet's surface by a survey, and he has shown that they have remained constant since the time of MAEDLER and KAISER. By a series of drawings, he has constructed a most admirable map of the planet. On this map he has located the continents and the seas; and has traced a very large number of 'canals' (narrow, straight, dark lines), and shown that many of them appear at times to be doubled. The elegant nomenclature he has adopted in his map will be a pleasure to the classical scholar who may examine it. It is a scholar's review of antiquity. Professor SCHIAPARELLI has, however, been very chary of hypotheses. . . . Most of his writings have been concerned with the pure results of observation, and he has scrupulously refrained from generalizations." *

Another says:—

> "He has extended our knowledge of the planet enormously in nearly every line,—in reference to the polar caps, the so-called seas and continents, but especially in reference to the so-called canals, their appearance and disappearance, their doubling, etc. His entire work bears the impress of a scientific spirit *par excellence*. His technical results are comprised in a few papers, and a dozen octavo pages suffice for a masterly popular exposition of his general results. His brief papers contain at least the suggestion of all the theories recently exploited by popular writers, though he was not concerned with establishing a theory, but rather with ascertaining facts." †

But SCHIAPARELLI would rank with the foremost astronomers of our time if he had never published a paper on *Mars* or made a drawing of the planet. Not one of the three gold medals he holds, nor of the two Lalande prizes, was awarded to him for his studies on *Mars*. In fact, the gold medals were bestowed upon him before his work on *Mars* began.

Like AUWERS and GILL, our medalists in 1899 and 1900, SCHIAPARELLI'S early training specially fitted him for his future work. After six years spent in the University of Turin as student, especially of mathematics, engineering, and astronomy, and private tutor in mathematics, he received in 1856 a position as instructor in mathematics at the gymnasium in Turin. He held this position for only two months, however, having received orders from the government to continue his astronomical studies under ENCKE at Berlin. We find him, accordingly, applying himself to these studies for the two following years, taking courses as well in mathematics, physics, meteorology, terrestrial magnetism, etc., under such famous professors as ERMAN, WEIERSTRASS, POGGENDORFF, ARNDT, and OHM. To supplement these theoretical studies he next went to Pulkowa, and there spent a year in practical astronomical work under OTTO STRUVE and WINNECKE. He was now thoroughly prepared to enter upon his life work, and on the 30th of June, 1860, a young man of 25, he was appointed Second Astronomer at the Milan Observatory, then under the directorship of Professor CARLINI.

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* Professor EDW. S. HOLDEN. *The Forum*, November, 1892.

† Professor W. W. CAMPBELL. *Science*, August 21, 1896.

Forty years later, on June 30, 1900, when he resigned his position as Director of the Milan Observatory, the astronomers of Italy in testimony of their appreciation of his work, published a pamphlet entitled "All' Astronomo G. V. Schiaparelli, Omaggio 30 Giugno 1860–30 Giugno 1900," which recounts in detail the story of his scientific life and gives a complete list of his writings. In their address on this occasion, they call attention to his discovery a few months after assuming his duties at Milan, of a minor planet, *Hesperia*,—an event of more interest and significance in those days than at present,—and continue:—

> "With this discovery, made so soon after your entrance in the Observatory di Brera, you began to draw the attention of the astronomical world upon your name, which, having quickly achieved greater titles to fame, the history of astronomy records with high honor, recalling your observations and your studies upon the comet of 1862; your theory of meteors; your many and accurate observations of double stars; your observations and discoveries upon the planets *Mercury* and *Venus*, and particularly *Mars*; your researches in and reconstruction of the story of the astronomical thought of ancient times; your careful study of the motion of the pole of terrestrial rotation, etc.; while the history of meteorology and of terrestrial physics and of natural philosophy in general will record your many contributions as of the highest importance."

It is obviously impossible to mention even the titles of all these important papers, to say nothing of giving an adequate account of their contents. In addition to the brief reference already made to his well-known observations on *Mars*, we must confine ourselves to a very short account of the researches first mentioned in the passage just quoted; his study of the comet of 1862, his theory of meteors, and his observations of double stars.

That comets and meteors are very closely related,—so closely as to point conclusively to a common origin,—is now so generally believed by astronomers, that it is hard to realize that their relationship was not clearly established until less than forty years ago. Such is nevertheless the fact. Though KEPLER, HALLEY, and one or two others conceived the idea that meteors were of cosmical origin, the prevailing belief to the close of the eighteenth century was that they were due to "atmospheric perturbations, exhalations of sulphur, *ignes fatui*, and so forth," while such eminent men as LAPLACE and OLBERS thought it more probable that the meteors were composed of matter discharged from volcanoes on the Moon. Observational data concerning these phenomena began to accumulate in the early part of the nineteenth century, observation being greatly stimulated by the *Leonid* shower witnessed by HUMBOLDT in 1799, and by the celebrated display of 1833. After seeing the latter, and reading HUMBOLDT'S account of the former, OLMSTED was led to the conclusion that the appearance was due to the Earth's passage "through a storm, so to speak, of planetary bodies." He also first detected that the meteors of a shower *radiate* from a definite region of the sky—the radiant point.

In the period from 1833 to 1866 progress was rapid. Observers in Europe and America were zealous in collecting data, and NEWTON, ADAMS, ERMAN, KIRKWOOD, A. S. HERSCHEL, and many others were eagerly seeking the solution to the problems presented. NEWTON traced the recurrence of the *Leonid* shower, at intervals of about thirty-three years, back to the year 902; ADAMS determined with great accuracy the revolution period of the swarm from which the shower proceeds; and at about the same time SCHIAPARELLI concluded that the orbit of this swarm must be an elongated ellipse resembling the orbits of comets, rather than the nearly circular planetary orbits. The existence of many other radiants in the sky was established, and the study of the so-called sporadic meteors brought to light the diurnal and annual variations in their frequency and the relation of these variations to the orbital motion of the Earth and to the movement of the solar system in space.

Finally, SCHIAPARELLI, in 1866, computing an orbit for the August meteors, the *Perseids*, upon the assumption that their path was nearly parabolic, arrived at elements that were practically identical with those of TUTTLE'S comet of 1862, and thus completed the proof of the cosmical origin of meteors.

SCHIAPARELLI, therefore, was but one of many toilers in this field, and as in the case of nearly all great advances in scientific thought, his discovery had been foreshadowed and almost anticipated by some of his predecessors. But this does not in the least detract from the merits of his achievement. The actual discovery was his, and it is his distinction that by approaching the problem from a higher point of view and bringing to bear upon it a keener power of analysis, he was able to correlate the diverse phenomena and frame a comprehensive theory that would account for them all. So thoroughly did his writings on this subject, from 1863 to 1872, cover the ground, and so clearly did they point out the lines along which investigation should proceed, and the difficulties that remained to be overcome, that it may be said that the progress of the past thirty years in this important branch of astronomy has been mainly the elaboration of his ideas.

So far we have called attention only to SCHIAPARELLI'S researches within our own system,—for meteors and comets may be regarded as at least temporary members of the family of the Sun,—but no sketch of his career, however brief and inadequate, can omit mention of his notable contributions to our knowledge of the systems of the stars.

A student under OTTO STRUVE, a friend of Baron DEMBOWSKI, it is not strange that he should have been attracted to the study of double stars. Nor, remembering his habits of thoroughness, persevering industry, and attention to details, is it surprising that both the quality and the quantity of his work in this field entitle him to rank with the STRUVES, DEMBOWSKI, and BURNHAM, as one of the great double-star observers of the century. Nearly 12,000 observations of double stars are the result of his twenty-five years' labors with the 8-inch Merz equatorial, from February 7, 1875, to May, 1886, and with the 18-inch Repsold equatorial, from 1886 on. As his observing-list has always included the more important systems in reach of his instrument, the more interesting binary stars often being measured on as many as ten or fifteen nights in a year, it would be difficult to overestimate the value of this great mass of material to the double-star student of the present day; and its value will increase rather than diminish with the lapse of time.

Though he has now retired from the directorship of the Milan Observatory, I do not understand that Professor SCHIAPARELLI has given up his astronomical studies. In the larger leisure that he now enjoys, we trust that he may continue the researches

that have made him famous, and may still further advance our knowledge of the worlds about us.

I hand the Bruce Medal to you, Mr. Secretary, to transmit to Professor SCHIAPARELLI with the assurance of the high esteem in which we all hold his name, and with the expression of our heartiest good wishes that he may long enjoy the honors to which his great services have entitled him.

March 29, 1902.

ASTRONOMICAL OBSERVATIONS IN 1901.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

VARIABLE STARS.

Z Cygni.[*]

January	10:	*Z* a little > d.
February	6:	= e.
March	14:	utmost faint.
April	21:	invisible.
May	21:	id.
June	29:	= c.
August	19:	> b.
September	2:	= b.
	12:	= c.
	21:	id.
	24:	id.
October	9:	= d.
	26:	< d.
	30:	< d. > e.
November	1:	= e.
	9:	< e.
	30:	invisible.

S Ursæ majoris.[†]

January	10:	*S* invisible.
February	6:	= g.
	11:	id.
	15:	= f.
	24:	> f. < e.
March	9:	= e.
	13:	id.
	20:	id.
	23:	id.
	29:	id.
May	4:	> d. < c.
	21:	id.
August	17:	invisible.
	24:	id.
September	2:	id.
	7:	< g.
	12:	id.
	19:	id.
September	21:	id.
	24;	id.

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[*] *Vide* the sketch in the *Publications* A. S. P., No. 48, page 69.

Vide the sketch in the *Publications* A. S. P., No. 73, page 56.

October	9:	= f.
	11:	id.
	26:	a little < e.
	29:	= e.
	30:	id.
November	1:	id.
	3:	id.
	9:	id.

November	20:	> e. < d.
	22:	id.
	24:	almost = d.
	26:	id.
	30:	id.
December	2:	id.
	4:	= d.

*T Ursæ majoris.**

January	10:	$T\left\{\begin{array}{l}<\text{c.}\\>\text{d.}\end{array}\right.$
February	6:	$\left\{\begin{array}{l}<\text{e.}\\>\text{f.}\end{array}\right.$
	11:	a little > f.
	15:	= f.
	24:	= g.
March	9:	invisible.
	13:	id.
	20:	utmost faint.
	23:	id.
May	4:	invisible.
	21:	id.
August	17:	a little > a.
	24:	$\left\{\begin{array}{l}<\text{a.}\\>\text{b.}\end{array}\right.$
September	2:	id.
	7:	id.
	12:	a little > b.
	19:	id.

September	21:	= b.
	24:	$\left\{\begin{array}{l}<\text{b.}\\>\text{c.}\end{array}\right.$
October	9:	$\left\{\begin{array}{l}<\text{c.}\\>\text{d.}\end{array}\right.$
	11:	= d.
	26:	= e.
	30:	id.
November	1:	id.
	3:	id.
	9:	$\left\{\begin{array}{l}<\text{e.}\\>\text{f.}\end{array}\right.$
	20:	invisible.
	22:	id.
	24:	id.
	26:	id.
	30:	id.
December	2:	id.
	4:	id.

W Pegasi.

January	10:	*W* invisible.
February	6:	very faint.
August	17:	= e.
September	2:	< e.
	7:	$\left\{\begin{array}{l}\text{a little} > \text{g.}\\\text{almost} = \text{f.}\end{array}\right.$
	21:	= h.

October	9:	very faint.
	29:	< h.
November	3:	id.
	9:	invisible
	30:	id
December	4:	id.

Nova Persei.

The star was discovered by THOMAS D. ANDERSON, in Edinburgh, on the 22d of February, in the forenoon, at half-past two o'clock, and was, before news about the discovery had reached our country, also seen by LAURSEN NORDVIG, in Maarslet, near

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* *Vide* the sketch in the *Publications* A. S. P., No. 22, page 63.

Aarhus, in Denmark. The following observations were made at Odder:—

Feb. 23, $6^h\ 30^m$ P.M. Brighter than *Capella*, $0^m.1$; blue white.
24, $5^h\ 30^m$ A.M. Brighter than *Vega*.
25, $7^h\ 30^m$ P.M. $0^m.80$.
28, $8^h\ 30^m$ P.M. $1^m.78$.
Mar. 4, 8^h P.M. A little $> \delta$ *Persei*.
9, 10^h P.M. $4^m.79$; deep red.
Mar. 13, $7^h 30^m$P.M. $\left\{\begin{array}{l} < \epsilon \textit{ Persei.} \\ > \nu \textit{ Persei.} \end{array}\right.$
19, 8^h P.M. 5–6^m; the sky partly clouded.
20, $7^h\ 30^m$ P.M. A little $< \nu$ *Persei*.
22, 8^h P.M. 5^m; deep red.
23, 9^h P.M. $= \nu$ *Persei* $= 3^m.9$.
26, 9^h P.M. 5^m.
29, $9^h\ 15^m$ P.M. $5^m.36$.

After this date the sky was overclouded for twenty-three days.

Apr. 21, 10^h P.M. $= 30$ Fl. $= 5^m.41$.
23, $9^h\ 30^m$ P.M. 4^m, very bright; with visual spectroscope a red line was seen.
24, $9^h\ 30^m$ P.M. $= 30$ Fl.
25, 10^h P.M. $5^m.6$.
28, 11^h P.M. $5^m.5$. Red.
May 1, $10^h\ 30^m$ P.M. 6^m.
3, $9^h\ 30^m$ P.M. $5^m.4$.
4, $9^h\ 30^m$ P.M. 6^m.
10, 11^h P.M. id.
13, $11^h\ 30^m$ P.M. $= 32$ Fl. $= 5^m.1$.
21, $10^h\ 30^m$ P.M. $5^m.8$.
June 29, $11^h\ 50^m$ P.M. 6^m.
July 20, 1^h A.M. 6^m.
Aug. 17, 10^h P.M. $6^m.4$.
19, 10^h P.M. $6^m.6$.
24, 10^h P.M. $6^m.3$.
Sept. 2, 9^h P.M. id.
3, 9^h P.M. id.
Sept. 7, 9^h P.M. id.
12, 10^h P.M. $6^m.6$.
20, $11^h\ 30^m$ P. M. id.
21, 9^h P.M. $6^m.5$.
24, 9^h P.M. id.
Oct. 9, 9^h P.M. id.
11, $7^h\ 30^m$ P.M. $7^m.0$.
29, 8^h P.M. $6^m.8$.
31, 6^h P.M. id.
Nov. 1, 8^h P.M. id.
2, 8^h P.M. id.
3, 8^h P.M. id.
9, 8^h P.M. id.
20, $6^h\ 30^m$ P.M. $7^m.2$.
22, 9^h P.M. $7^m.5$.
23, 11^h P.M. $7^m.2$.
26, 6^h P.M. id.
30, 6^h P.M. $7^m.0$.
Dec. 4, 6^h P.M. $7^m.5$.
6, $6^h\ 30^m$ P.M. $7^m.2$.
8, 9^h P.M. id.

SHOOTING STARS.

Simultaneous observations on meteors were made from several stations in Denmark and Sweden. From the northwestern rampart of the ancient Uranienborg, where TYCHO BRAHE made his admirable observations, more than three hundred years ago, I watched the shooting-stars on the 9th, 10th, and 11th of August, and the paths of one hundred such meteors were drawn upon the map. From all the stations 417 meteors were observed.

FIREBALLS.

In the past year seventeen fireballs have been seen from stations in Denmark.

No.	Time. h m	Beginning.	End.	Mag.	Station.	Note.
1	Jan. 17, 4 16 P. M.	WNW. 45° alt.	NNW.	1	Copenhagen...	Exploded into three or four parts. Seen from several stations.
2	21, 10 28	160° + 50°	177° + 24°	1	Hellerup......	White meteor, lasting 4 seconds.
3	22, 12 32 A. M.	96° — 7°	115° — 20°	♀	Præstö........	Very slow; duration 5 seconds; was at first of the third magnitude.
4	29, 8 30 P. M.	......	E.	*	Lidsted (Bornholm).	Large meteor, with a bright train; whistling in the air; after three minutes three detonations were heard.
5	Feb. 12, 6 10	......	Below *Sirius.*	*	Hareskov.....	Red; large train.
6	24, 11 50	......	......	*	Kolding.......	Explosion; the pieces of various colors.
7	28, 6 10	*Cassiopeia.*	30° + 40°	1·4☾	Copenhagen...	Yellow; train.
8	April 23, 10 17	279° + 42°	320° + 48°	1·5☾	Copenhagen...	
9	Aug. 14. 9 50	......	......	*	Lyngby.......	
10	15, 10 15	......	......	*	Hovedgaard...	Explosion.
11	18, 10 15	270° + 82°	202° + 27°	*	Olstrup	Train, lasting 5 seconds.
12	24, 10 43	307° + 13°	315° — 2°	♀	Odder	Orange; duration 4 seconds.
13	Sept. 8, 10 16	32.5° + 32°	20° + 20°	♀	Copenhagen...	Train, lasting 4·5 seconds.
14	Oct. 6, 10 42	158° + 56°	118° + 32°	*	Maarslet	Red; very slow; duration of the movement 15 seconds. Also seen at Odense.
15	Nov 15, 12 30 A. M.	*Leo-Camelopardalus.*	*Cassiopeia-Pegasus.*	*	Veile	Train for 30 seconds.
16	16, 10 25 P M.	57° + 15°	76° — 2°	♀	Veile	Red; explosion; duration 6 seconds; was at first of the third magnitude. Also seen at Copenhagen.
17	Dec. 9, 9 0	E.	W.	*	Strö	Horizontal path; slow.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1902.

By Malcolm McNeill.

May.

There will be a partial eclipse of the Sun on May 7th. It is rather larger than the one on April 8th, the maximum obscuration being about five sixths of the Sun's diameter, but it is visible only in the South Pacific. New Zealand is about the only large land-mass in its path.

Mercury is an evening star throughout the month, having passed superior conjunction on April 28th. At the beginning of May it is too near the Sun to be seen; but by the end of the first week it is far enough away to show in the evening twilight, and for the last ten days of the month it remains above the horizon nearly two hours after sunset. It reaches greatest east elongation (23°) on May 28th. This is rather smaller than the west elongation in March, but is better than the east elongation in February. It gives the best opportunity of the year for seeing the planet.

Venus is still morning star, and throughout the month rises about two hours before sunrise. It passed its greatest west elongation in April, and the distance between the planet and the Sun is beginning to diminish, but the rate is as yet very slow, less than 1° for the month.

Venus will be perceptibly less bright than it was during April, but no other planet will compare with it.

Mars is drawing a little farther away from the Sun, but is still too near for naked-eye observation. By the end of the month it rises a little less than an hour before sunrise. It reaches its maximum distance from the Earth on May 20th. It is then 226,000,000 of miles away from us, about 8,000,000 less than its average maximum.

Jupiter rises earlier than during April — before midnight by the end of May; so it is getting into good position for early-morning observation. It is still in the constellation *Capricorn*, and moving eastward, but at a much diminished rate, only 2° during the month.

Saturn rises about an hour earlier than *Jupiter*, and by the end of the month is far enough above the horizon to be seen with the naked eye at midnight. It ceases its eastward motion among the stars on May 8th and begins to retrograde, but very slowly. Naked-eye observations will show very little change in its position during the month.

Uranus rises early enough for late evening observations toward the close of the month. It is in *Ophiuchus* between *Sagittarius* and *Scorpio*, and moves about 1° westward during the month.

Neptune is still in the evening sky, but sets earlier. It is in conjunction with *Mercury*, the latter passing about 3° north, on May 29th.

JUNE.

The Sun reaches its maximum declination at the summer solstice June 22d, 1 A.M., Pacific time.

Mercury is still an evening star, and remains in good position for observation until nearly the middle of the month. This prolonged period of visibility — over a month — is due partly to the fact that it is in aphelion on June 17th, and hence its elongation from the Sun is greater than the average. After the middle of the month it rapidly approaches the Sun and reaches inferior conjunction on June 23d.

Venus still keeps up its relative position with respect to the Sun, and the interval between the rising of the planet and that of the Sun increases about a quarter of an hour, although the apparent distance diminishes about 2°. The reason for the increased interval is, that *Venus* is still moving northward, while the Sun begins to move southward at the solstice, on June 22d, this causing a greater change in relative time of rising than the change in the opposite direction caused by diminution of distance.

Mars is drawing a little farther away from the Sun, and by the end of the month rises about an hour and a half before sunrise; but it will not be an easy object, on account of its faintness.

At the end of June *Jupiter* will rise before 10 P.M.. It ceases its eastward motion and begins to move westward on June 6th. By the end of the month it will have moved about 1°, and will be in about the same position it held in the middle of May, in the eastern part of *Capricorn*.

Saturn is in the western part of the same constellation, and is also moving westward, not quite 2° during the month. It can now be made out easily, before midnight or earlier, toward the end of the month.

Uranus is above the horizon practically the whole night, and comes to opposition on June 10th. It moves westward about 1°.

At the beginning of the month it is a little less than 2° north of the third-magnitude star *θ Ophiuchi.*

Neptune is in conjunction with the Sun on June 23d, and changes from an evening to a morning star.

MAY–JUNE, 1902.

PHASES OF THE MOON, P. S. T.

New Moon . . .	May 7,	2^{h}	45^{m}	P.M.
First Quarter . . .	May 14,	5	40	A.M.
Full Moon . . .	May 22,	2	46	
Last Quarter . . .	May 30,	4	00	
New Moon . . .	June 5,	10	11	P.M.
First Quarter . . .	June 12,	3	54	
Full Moon . . .	June 20,	6	17	
Last Quarter . .	June 28,	1	52	

THE SUN.

1902.		R. A.	Declination	Rises.		Transits.		Sets.	
May	1,	$2^{h}\ 31^{m}$	$+14^{\circ}52'$	$5^{h}\ 5^{m}$	A.M.	$11^{h}\ 57^{m}$	A.M.	$6^{h}\ 49^{m}$	P.M.
	11,	3 10	+17 42	4 55		11 56		6 57	
	21,	3 49	+20 03	4 45		11 56		7 7	
	31,	4 30	+21 49	4 39		11 57		7 15	
June	10,	5 11	+22 58	4 36		11 59		7 22	
	20,	5 52	+23 26	4 36		12 1	P.M.	7 26	
	30,	6 34	+23 13	4 39		12 3		7 27	

MERCURY.

May	1,	2 42	+15 56	5 12	A.M.	12 8	P.M.	7 4	P.M.
	11,	4 6	+22 40	5 31		12 53		8 15	
	21,	5 19	+25 27	5 52		1 26		9 00	
	31,	6 8	+24 57	6 4		1 36		9 8	
June	10,	6 27	+22 39	5 54		1 15		8 36	
	20,	6 14	+20 03	5 12		12 23		7 34	
	30,	5 52	+18 44	4 15		11 21	A.M.	6 27	

VENUS.

May	1,	23 39	+ 2 56	3 15	A.M.	9 5	A.M.	2 55	P.M.
	11,	0 18	+ 0 29	3 4		9 5		3 6	
	21,	0 58	+ 4 13	2 52		9 6		3 20	
	31,	1 40	+ 8 3	2 41		9 8		3 35	
June	10,	2 23	+11 48	2 31		9 11		3 51	
	20,	3 8	+15 16	2 23		9 16		4 9	
	30,	3 54	+18 16	2 20		9 24		4 28	

MARS.

May	1,	2 4	+12 10	4 49	A.M.	11 30	A.M.	6 11	P.M.
	11,	2 32	+14 41	4 28		11 19		6 10	
	21,	3 1	+16 58	4 10		11 9		6 8	
	31,	3 31	+18 58	3 51		10 58		6 5	
June	10,	4 0	+20 39	3 36		10 49		6 2	
	20,	4 30	+21 59	3 20		10 39		5 58	
	30,	5 0	+22 59	3 6		10 29		5 52	

Jupiter.

May	1,	21 12	— 16 46	1 37 A.M.	6 39 A.M.	11 41 A.M.
June	1,	21 20	— 16 19	11 42 P.M.	4 45	9 48
July	1,	21 16	— 16 43	9 41	2 43	7 45

Saturn.

May	1,	19 59	— 20 35	12 39 A.M.	5 26 A.M.	10 13 A.M.
June	1,	19 58	— 20 43	10 37 P.M.	3 23	8 9
July	1,	19 51	— 21 4	8 33	1 18	6 3

Uranus.

May	1,	17 20	— 23 12	10 7 P.M.	2 43 A.M.	7 19 A.M.
June	1,	17 15	— 23 8	8 4	12 41	5 18
July	1,	17 10	— 23 2	5 56	10 33 P.M.	3 10

Neptune.

May	1,	5 57	+ 22 20	8 3 A.M.	3 23 P.M.	10 43 P.M.
June	1,	6 2	+ 22 21	6 4	1 25	8 46
July	1,	6 6	+ 22 21	4 11	11 32 A.M.	6 53

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope.)

I, D,	May	7,	4^h 56^m A.M.
II, D,		7,	11 55 P.M.
I, D.		8,	11 24 P.M.
II, D,		15,	2 29 A.M.
I, D,		16,	1 19 A.M.
I, D,		23,	3 12 A.M.
I, D,		24,	9 41 P.M.
I, D,		31,	11 35 P.M.

III, D,	June	1,	9^h 19^m P.M.
III, R,		2,	12 50 A.M.
IV, D,		6,	11 26 P.M.
IV, R,		7,	3 59 A.M.
I, R,		8,	1 29 A.M.
II, D,		8,	11 27 P.M.
III, D,		9,	1 19 A.M.
III, R,		9,	4 50 A.M.
I, D,		15,	3 23 A.M.
II, D,		16,	2 1 A.M.
I, D,		16,	9 12 P.M.
II, D,		23,	4 35 A.M.
IV, R,		23,	10 7 P.M.
I, D,		23,	11 46 P.M.

APPROXIMATE ELEMENTS OF THE ORBITS OF THE COMETS FROM 1896 TO 1901.

By W. J. Hussey.

In number 50 of these *Publications* (June, 1896), a number of tables compiled by the late Professor Winlock are printed, giving the approximate elements of all computed orbits of comets from B. C. 372 to A. D. 1896. The following table of the approximate elements of the comets which have appeared during the years 1896 to 1901, inclusive, is intended as a continuation of Professor WINLOCK'S first table, and it is arranged in the same manner:—

APPROXIMATE ELEMENTS OF THE ORBITS OF THE COMETS FROM 1896 TO 1902.

Number.	T			ω	☊	i	q	a	P	e	Discoverer.
420......	1896	I	Jan. 31.8	358°.5	254°.8	155°.9	0.588	....	....	....	PERRINE.
421 F....	1896	II	Mar. 19.3	201 .2	209 .8	11 .3	1.738	3.854	7ʸ.57	0.549	
422......	1896	III	April 17.6	1 .7	178 .3	55 .6	0.566	....	....	....	SWIFT.
423......	1896	IV	July 10.9	41 .0	151 .0	88 .4	1.142	....	....	....	SPERRA.
424......	1896	V	Oct. 26.0	139 .5	192 .1	11 .6	1.482	3.500	6 .55	0.657	GIACOBINI.
425 Bro..	1896	VI	Nov. 4.2	343 .8	18 .0	6 .1	1.959	3.684	7 .072	0.469	
426......	1896	VII	Nov. 24.6	163 .9	246 .6	13 .7	1.110	3 462	6 .441	0.677	PERRINE.
427......	1897	I	Feb. 8.1	172 .3	86 .3	146 .1	1.062	....	....	....	PERRINE.
428 d'A..	1897	II	May 27.3	173 .0	146 .3	15 .7	1.324	3.551	6 .691	0.627	
429......	1897	III	Dec. 8.8	66 .1	32 .1	69 .6	1.356	....	....	....	PERRINE.
430......	1898	I	Mar. 17.4	145 .1	262 .5	72 .5	1.099	....	....	....	PERRINE.
431 W...	1898	II	Mar. 20.4	173 .3	100 .9	17 .0	0.924	3.235	5 .818	0.725	
432 E. ..	1898	III	May 27.8	184 .0	334 .8	12 .9	0.341	2.218	3 .303	0.846	
433 Wo..	1898	IV	July 4.6	172 .9	206 .5	25 .2	1.604	3.597	6 .821	0.557	
434......	1898	V	July 25.5	22 .4	278 .3	166 .9	1.501	....	....	....	GIACOBINI.
435......	1898	VI	Aug. 16.2	205 .6	259 .1	70 .0	0.627	....	....	....	PERRINE.
436......	1898	VII	Sept. 14.1	233 .3	74 .0	69 .9	1.702	....	....	....	CODDINGTON.
437......	1898	VIII	Sept. 20.1	4 .6	91 .8	22 .5	2.269	....	....	....	CHASE.
438......	1898	IX	Oct. 20.5	162 .4	34 .9	28 .9	0.420	....	....	....	PERRINE.
439......	1898	X	Nov. 23.2	123 .6	96 .3	140 .4	0.756	....	....	....	BROOKS.
440......	1899	I	April 13.0	9 .0	25 .1	146 .3	0.325	....	....	....	SWIFT.
441 Ho..	1899	II	April 27.7	14 .1	331 .7	20 .8	2.128	3.615	6 .90	0.411	
442 Tu..	1899	III	May 4.5	206 .7	269 .9	54 .5	1.024	5.724	13 .76	0.822	
443 T2 .	1899	IV	July 28.5	185 .6	121 .0	12 .6	1.389	3.033	5 .281	0.542	
444......	1899	V	Sept. 15.0	10 .9	272 .2	76 .9	1.785	....	....	....	GIACOBINI.
445......	1900	I	April 29.1	24 .6	40 .4	146 .4	1.329	....	....	....	GIACOBINI.
446......	1900	II	Aug. 3.2	12 .4	328 .0	62 .5	1.015	....	....	....	BROOKS-BORRELLY.
447......	1900	III	Nov. 28.3	171 .5	196 .5	29 .9	0.934	3.617	6 .66	0.742	GIACOBINI.
448......	1901	I	April 24.3	203 .0	109 .6	131 .1	0.245	....	....	....	(Great Comet).
449 E. ..	1901	II	Sept. 15.3	184 .0	334 .8	12 .9	0.341	2.219	3 .303	0.846	

The abbreviations used in the first column to designate the periodic comets on their return to perihelion are as follows:

d'A. = D'ARREST'S comet.
Bro. = BROOK'S comet.
E. = ENCKE'S comet.
F. = FAYE'S comet.
Ho. = HOLME'S comet.
T2 = TEMPEL'S second periodic comet.
Tu. = TUTTLE'S comet.
W. = WINNECKE'S comet.
Wo. = WOLF'S comet.

THE STARS: A STUDY OF THE UNIVERSE. BY PROFESSOR SIMON NEWCOMB.—A REVIEW.

By W. W. Campbell.

Centuries ago the starlike points that we see in the sky were classified as planets (wanderers) and fixed stars. Modern observations have shown that the term fixed is a misnomer: that the stars are in reality moving more rapidly, on the average, than the planets. Professor Newcomb has appropriately chosen the simple title of "The Stars" for his most interesting and suggestive book.

The study of the stars resolves itself into the consideration of two great subjects,—perhaps the greatest subjects in the whole realm of pure knowledge, viz.:—

I. *The Structure of the Universe.*
II. *The History of the Universe.*

All the researches of the astronomers of the past and present are but minor contributions to the solution of these main problems. Professor Newcomb's book touches lightly upon the second subject — indeed the present-day data are entirely too meager to warrant its serious consideration;— but he has entered boldly upon a determination of the Structure of the Universe. He has written excellent chapters on the cataloguing, the photometry, the motions, the parallaxes of the stars; and the seven concluding chapters, combining the results in the various departments of investigation in an effort to solve the main problem, are of surpassing interest. The scope of the book will be realized best from the following extract (Chapter XIV): —

> "First, we may inquire as to the extent of the universe of stars. Are the latter scattered through infinite space, so that those we see are merely that portion of an infinite collection which happens to be within reach of our telescopes, or are all the stars contained within a certain limited space? In the latter case, have our telescopes yet penetrated to the boundary in any direction? In other words, as, by the aid of increasing telescopic power, we see fainter and fainter stars, are those fainter stars at greater distances than those before known, or are they smaller stars, contained within the same limits as those we already know? Otherwise stated, do we see stars on the boundary of the universe?
>
> "Secondly, granting the universe to be finite, what is the arrangement of the stars in space? Especially, what is the relation of the galaxy to

the other stars? In what sense, if any, can the stars be said to form a permanent system? Do the stars which form the Milky Way belong to a different system from the other stars, or are the latter a part of one universal system.

"Thirdly, what is the duration of the universe in time? Is it fitted to last forever in its present form, or does it contain within itself the seeds of dissolution? Must it, in the course of time, in we know not how many millions of ages, be transformed into something very different from what it now is? This question is intimately associated with the question whether the stars form a system. If they do, we may suppose that system to be permanent in its general features; if not, we must look further for our conclusion."

In considering these questions, NEWCOMB has taken the view of modern science that "no answer is valid unless based on careful observation." The facts of observation described in the preceding chapters are made to bear with excellent judgment and great skill. The valuable but more limited investigations by SEELIGER, KAPTEYN, SCHIAPARELLI, and others are utilized — due credit being given. It is impossible to describe in a short article the methods of solution followed; the hundred pages of the book devoted to their consideration cannot be condensed, but must be read as a whole.

A few of the many conclusions arrived at are as follows:—

1. If we consider as of unit volume the sphere whose radius is 200,000 times the Earth's distance from the Sun, we may say that there is one star on the average for eight units of volume.

2. That collection of stars which we call the universe is limited in extent. . . . This does not preclude the possibility that far outside of *our* universe there may be other collections of stars of which we know nothing.

3. The boundary of our universe is probably somewhat indefinite and irregular. As we approach it the stars may thin out gradually. The parallax at the boundary is probably no where greater than 0".001, and may be much less. The time required for light to pass over the corresponding interval is more than 3,000 years.

4. The universe extends further around the girdle of the Milky Way than towards the poles of that girdle.

5. The total number of the stars is to be counted by the hundreds of millions.

The work, as a whole, contains a vast amount of information, stated philosophically and in a manner adapted to the needs of the working astronomer, as well as to the comprehension of the general reader. The author's greater experience along mathematical lines is the satisfactory explanation for a weakness here and there in the astrophysical chapters. As a case in point, the latter part of page 188, on the spectra of the nebulæ, should be rewritten for subsequent editions. The strong chapters are those in which the author has used the statistical method, and it is fortunate that his ripe judgment was brought to bear upon these difficult problems.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

OBSERVATIONS OF THE SATELLITES OF *SATURN*.

This series of observations — viz., those given in the *Bulletin* of the Lick Observatory, No. 17 — includes my measurements of the relative positions of all the satellites of *Saturn* except *Iapetus*, the one most distant from the planet; also, measurements of the directions and distances of *Enceladus*, *Tethys*, *Dione*, *Rhea*, *Titan*, and *Hyperion* from the center of the planet. The latter measurements were difficult to make, owing to *Saturn's* large size and the unsymmetrical form of the visible portion of the planet's disc. During the years in which these observations were made the rings had about their maximum opening, and a considerable portion of the planet's southern hemisphere was concealed beneath them. In 1898 and in 1901 its south polar region was invisible. This made it impossible to obtain complete sets of measures of the rectangular coordinates of the satellites from the preceding and following limbs and from the poles of the planet, and such measures were therefore not attempted. The position-angles and distances were obtained by bisecting the disc of the planet with the micrometer-wire. My judgment as to the position of the center of the disc was formed partly by considering the shape and size of the visible portion of the disc and what would have to be added to it to render its outline truly elliptical, and partly from the configuration formed by the inner edge of the ring and the outline of the planet.

Measurements of the relative positions of two satellites can be made with comparative ease, and the results so obtained are less subject to large systematic and accidental errors than those just described. It appears quite certain that improvement in the theories of the motions of the satellites of *Saturn* will be made largely by means of the observations of the relative positions of the satellites themselves. On this account, in the present series, it has been the first object to secure as many measures of this kind as possible. During the past year the only satellites connected directly with the planet were the remote ones, *Titan* and *Hyperion*. W. J. HUSSEY.

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* Lick Astronomical Department of the University of California.

RESIDUALS FOR OBSERVATIONS OF THE SATELLITES OF *URANUS* AND *NEPTUNE*.

I have compared my observations of the satellites of *Uranus*, made in 1897 and 1898, with places computed by means of Professor NEWCOMB'S tables of their motions, given in Appendix I of the Washington Observations for 1873. The average values of the residuals, in the sense O–C, are as follows:—

Ariel	+ 1°.5	— 0″.19
Umbriel . .	+ 2 .0	+ 0 .12
Titania . . .	+ 1 .3	— 0 .05
Oberon . . .	+ 0 .6	— 0 .17

These residuals, like those recently published by Professor AITKEN, show that the satellites are slightly in advance of their predicted places. The differences, however, between the observed and computed position-angles are very small, and would vanish if the adopted mean motions were very slightly increased.

I have also compared my observations of the satellite of *Neptune* with places computed by means of Dr. HERMANN STRUVE'S elements. The average values are as follows:—

Satellite of *Neptune* . . + 0°.2 + 0″.33

These elements represent the observation on angle with great exactness, all the residuals being of the same order of magnitude as the probable errors of observation. W. J. HUSSEY.

THE PRESSURE OF HEAT AND LIGHT RADIATION.

At the meeting of the American Association for the Advancement of Science, held in Denver in August, 1901, a paper* by Professor E. F. NICHOLS and Mr. G. F. HULL, of Dartmouth College, was read, giving an account of their experiments in determining the pressure of heat and light. A paper on the same subject was read by Professor NICHOLS at the meeting of the Astronomical and Astrophysical Society of America at Washington, in December, 1901.

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* Published in the *Physical Review*, Vol. XIII, No. 5, November, 1901.

The experimental proof that such a pressure is exerted by light is of great importance to astronomy. Such a property of light offers a reasonable explanation of several very perplexing phenomena, and will doubtless be found to assist materially in the solution of others.

Pressure of this character was first suggested by MAXWELL in dealing theoretically with the stresses in an electromagnetic field. BARTOLI later announced that a similar pressure was essential to one of the fundamental laws of thermodynamics. He failed, however, to detect such an effect experimentally, from the difficulty of isolating the phenomenon. Other investigators have discussed the problem theoretically, and especially the applications of such a pressure to the solution of various observed phenomena, in which many interesting results have been reached. The experimental solution had failed, however, owing to the action of gases surrounding the body experimented upon which it was found impossible to eliminate. The molecules of such gas exerted pressure which completely masked the force which it was sought to measure.

Following are the considerations acted upon by NICHOLS and HULL in their successful attempt to isolate this force :—

"1. The surfaces which receive the radiation, the pressure of which is to be measured, should be as perfect reflectors as possible. This will reduce the gas-action by making the rise of temperature due to absorption small, while the radiation-pressure will be increased; the theory requiring that a beam, totally reflected, exert twice the pressure of an equal beam completely absorbed.

"2. By studying the action of a beam of constant intensity upon the same surface surrounded by air at different pressures, certain pressures may be found where the gas-action is smaller than at others.

"3. The apparatus—some sort of torsion-balance—should carry two surfaces systematically placed with reference to the rotation-axis, and the surfaces on the two arms should be as nearly equal as possible in every respect save one—the forces due to radiation and gas-action should have the same sign on one side and opposite signs on the other. In this way a mean of the resultant forces on the two sides should be, in part at least, free from gas-action.

"4. Radiation-pressure, from its nature, must reach its maximum value instantly, while observation has shown that the gas-action begins at zero and increases with length of exposure, rising rapidly at first, then more slowly to its maximum effect, which, in most of the cases observed, was not reached until the exposure had lasted from 2½ to 3 minutes. For large gas-pressures, an even longer exposure was necessary to reach stationary conditions. The gas-action may be thus still further reduced by a ballistic or semi-ballistic method of measurement."

The apparatus for the observation of these pressures consisted of a delicate and especially arranged torsion-balance carrying two small glass vanes, one on either side of the rotation axis. Each of the vanes had one of its sides silvered and highly polished. These vanes were so hung that the glass face of one and the silvered face of the other were turned to the light. A beam of light from an arc-lamp was allowed to fall in turn upon each vane, and the deflection of the balance read by a telescope in which was observed the image of a scale reflected in a small mirror attached to the balance. At the same time that the deflection of the vanes was observed the intensity of the beam of light was observed by means of a thermopile and galvanometer. The balance was placed in a bell-jar which was connected with an air-pump and a large part of the air exhausted. The first observations consisted in allowing the beam of light to fall upon each vane for a sufficient time to allow the conditions of gas-pressure and radiation-pressure to become stationary, as indicated by the balance coming to rest. This was done for each vane in succession, and observations made at eight gas-pressures between 0.06^{mm} and 96^{mm} of mercury. The results, however, showed such complicated gas-actions at certain pressures that no certain conclusions could be drawn as to the existence of a constant force such as that sought. A comparison of these observations with the more accurate ones obtained later by means of short exposures, showed that in the first series the gas-action varied from one tenth to 6 or 7 times the actual pressure of light.

In the method of short exposures the light was allowed to fall on the vane for 6 seconds, which was one fourth of the period of vibration of the balance and the resulting deflection computed from the known laws of such a system. In this way very definite results were secured, as shown in the following table :—

p	*d*
96.0	19.7
67.7	21.0
37.9	21.6
36.5	22.1
33.4	21.1
1.2	20.9
0.13	26.8
0.06	23.2
Mean,	22.5

The column p gives the gas-pressure in the bell-jar in millimeters of mercury, and column d the permanent deflection in millimeters due to radiation-pressure. From the known constant of the torsion-balance this deflection gives 1.05×10^{-4} dynes as the radiation pressure.

By means of a bolometer constructed for the purpose, the energy of the radiation causing these deflections was measured, and it was found to correspond to a pressure of 1.34×10^{-4} dynes. The observations, therefore, show 78 per cent. of the total pressure of the beam indicated by the bolometer measurements. Some of the sources of error in the bolometer results which would tend to bring the observations into better agreement are indicated by the investigators.

According to a letter from Professor NICHOLS, later observations with improved apparatus have reduced the difference between the pressure of the radiation as measured directly and that indicated from theory, through measurements of the beam of light with the bolometer, to 5 per cent. This difference is extremely small, considering the difficult nature of the observations.

Ten years ago LEBEDEW explained the anomalous appearances exhibited by the tails of comets by assuming such a pressure of light to act in opposition to the Sun's attractive force. Such a theory accounts for the different types of cometary tails by supposing that the individual particles composing them are of different sizes.

As the velocity due to gravity depends upon the *mass* of the particle, while the velocity due to radiation-pressure depends upon the *surface*, the resultant will be different for particles of different sizes. Comparatively large particles will obey the force of gravity, while in the case of the smaller ones the radiation-pressure will be most effective and will cause them to move in opposition to gravity. The smallest rapidly moving particles would thus compose the long, straight tails of comets, while the short, curved tails would be composed of larger particles. Particles still larger would be acted upon sufficiently by gravity to cause them to move towards the Sun.

This explanation of cometary phenomena has recently been revived by ARRHENIUS, and the theory of radiation-pressures extended to cover a number of other phenomena — e. g., the Zodiacal Light, Gegenschein, Aurora Borealis, etc.

This property of radiation must be nearly as wide-spread as gravity itself, and will have to be considered in all theories relating to finely divided matter at least.

It is perhaps not too much to expect that ere long we shall know much more of this new property of light and heat, especially its relations to different wave-lengths.

C. D. PERRINE.

MT. HAMILTON, CALIFORNIA, March 19, 1902.

ORIGIN OF A DISTURBED REGION OBSERVED IN THE CORONA OF 1901, MAY 17–18TH.

One of the most conspicuous features of the recent eclipse was an area of disturbance in the Corona off the east limb, to which I called attention in my first reports.*

The disturbance had the form of an inverted cone, with its apex on or very near the Sun's limb. It had the appearance of being composed of cloudlike masses of matter, arranged in such a manner as we should expect if it were the result of an eruption on the Sun's surface. In fact, the appearance alone very strongly suggests such an origin. Close to the apex of this region is a long, slender prominence, almost tangential to the limb, which seems to have had its origin at the same point as the coronal disturbance.

No spots or unusual faculæ had been observed just previous to the eclipse, nor were any observations or photographs available until recently with which to investigate the question of origin. Through the kindness of the Astronomer Royal, Royal Observatory, Greenwich, the Lick Observatory has been supplied with copies on glass of the negatives of the Sun taken at Dehra Dûn, India, on May 17, 18, 19, 20, 21, 22, 26, and 28, 1901. These photographs are on a scale of 7½ inches to the solar diameter and furnish the requisite data.

The photographs of May 17th and 18th show no spots or other evidences of unusual activity on any part of the Sun's disc. On the photograph of May 19th, however, is a spot of medium size which has just appeared around the east limb. Owing to foreshortening, the spot, on this date, is little more than a line ½′ in length, surrounded by faculæ. On the 20th it is ¾′ in length (north and south), and is followed at a distance of ½′ by several small spots, forming a close group.

The principal spot is compact, with well-defined umbra and penumbra, and shows no unusual changes during the interval covered by the photographs. The group of small spots following, however, shows considerable growth.

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* Lick Observatory *Bulletin*, No. 9. *Publications A. S. P.*, Vol. XIII, p. 196.

The following coordinates of the principal spot have been deduced from the plates of May 19th and 28th, the longitudes being measured from the center of the disc:—

	Greenwich Civil Time.	Longitude.	Latitude.
1901 May 19,	3h 30m 37s	80°.7 East	+9°.0
28,	7 29 37	46 .7 West	+9 .0

From these positions, the spot was found to occupy the following position at the time of the eclipse in Padang:—

	Greenwich Mean Time.	Longitude.	Latitude.
1901 May 17,	17h 40m 37s	93°.8 East	+9°.0

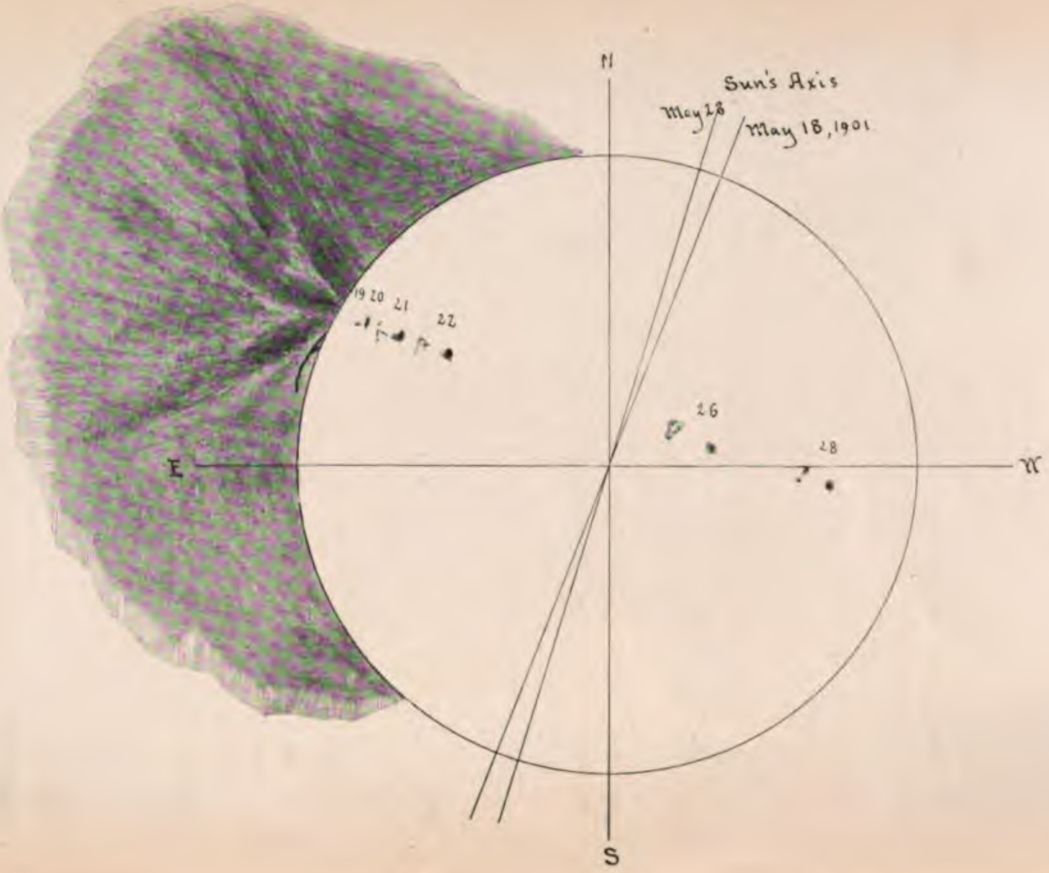
Thus the spot was on the opposite side of the Sun at the time of the eclipse and within 4° of the limb. Following are the position-angles of the spot as projected on the limb, and of the apex of the disturbed area in the corona observed on the eclipse negatives.

	Position Angle.
Sun-spot	60°.2
Apex of coronal disturbance	60 .0

During the period of eleven days covered by the photographs, only this one group of spots was visible. In this time almost the entire solar surface was under observation.

From the above position-angles it is seen that this group of sun-spots occupied the same line of sight as the apex of the disturbed coronal region. The accompanying illustration makes this clear. The spots have been copied from the Dehra Dûn photographs, and the principal masses of the coronal disturbance were sketched in to the same scale, from the eclipse negatives taken with the 40-foot camera.

We have no means of determining the position *in the line of sight* of the apex of the coronal disturbance other than that afforded by the angle of the cone-shaped area. This indicates an origin near the limb. It can, therefore, hardly be doubted that this disturbed region in the corona was in reality immediately above the group of sun-spots and faculæ, and that it had its origin in the same disturbance of the Sun's surface. The long, threadlike prominence alluded to seems likewise to have originated in the same group of spots and faculæ.


N
Sun's Axis
May 28
May 18, 1901
19 20 21
22
26
28
E
W
S

These observations indicate very strongly the intimate connection of all solar phenomena. Sun-spots, faculæ, prominences, and corona all seem, in this instance at least, to have had a common origin.

The undoubted connection of this coronal disturbance with the group of spots and faculæ on the surface, and its appearance so strongly suggested great activity, that a set of measurements was made of some of the best-defined masses to see if motion could be detected. The greatest interval of time available between photographs of the corona suitable for this purpose was but slightly over five minutes; yet velocities of 50 or 100 miles per second should be easily detected. The results fail to show any certain indication of motion. The uncertainties of measurement of such masses are so large, however, that velocities of 5 or 10 miles per second would not be detected. It may be said with confidence that the velocities at right angles to the line of sight were not as great as 20 miles per second. A comparison of negatives of the corona extending over a larger interval of time—e. g., those secured in Mauritius and Sumatra—would be valuable in this connection.

C. D. PERRINE.

MT. HAMILTON, CALIFORNIA, 1902, March 17th.

ASTRONOMICAL TELEGRAMS.

(Translations.)

CAMBRIDGE, MASS., Feb. 2, 1902.

To Lick Observatory: (Received 4:30 P.M.)

Kiel cables that SCHWAB'S *Algol* variable 93, 1901, will be at minimum on Feb. 3.89 Green. M. T. Its period is 3.38 days.

(Signed) E. C. PICKERING.

CAMBRIDGE, MASS., Feb. 4, 1902.

To Lick Observatory: (Received 6:35 P.M.)

HALE telegraphs that PARKHURST found SCHWAB'S variable to be of magnitude 8.45 at $23^h\ 46^m$ G. M. T. Feb. 3; and of magnitude 8.10 at $0^h\ 29^m$ G. M. T. Feb. 4.

(Signed) E. C. PICKERING.

MOUNT HAMILTON, CAL., Feb. 10, 1902.

To Harvard College Observatory,
Cambridge, Mass. (Sent 9:45 A.M.)

PERRINE finds that the remarkable coronal disturbance seen at the Sumatra eclipse was immediately above the prominent and only sun-spot visible during eleven days.

(Signed) W. W. CAMPBELL.

MOUNT HAMILTON, CAL., March 13, 1902.

To Harvard College Observatory,
Cambridge, Mass.

(Sent 4:14 P.M.)

From recent Crossley photograph, PERRINE finds no evidence of polarization in condensations A and D of the nebula surrounding *Nova Persei*.

(Signed) W. J. HUSSEY, (in charge).

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

Professor F. P. BRACKETT, kindly sent to the Society a report of the observations of the *Leonids* made by volunteers from the astronomy class of Pomona College, on the mornings of November 14, 15, and 16, 1901. Unfortunately, the manuscript was received too late for insertion in our last number. As the observations have since then been printed in *Popular Astronomy* (March, 1902, p. 165), we shall merely summarize them. In all, 1,590 meteors were seen on the three mornings, 1,483 of them being *Leonids*. The thick of the shower came between 3:00 and 5:30 A.M., November 15th, reaching a climax between 4:30 and 5:00 A.M., when 400 were seen in half an hour, the average interval being 4 seconds. The least time for ten meteors was 15 seconds from $4^h\ 0^m\ 15^s$ to $4^h\ 0^m\ 30^s$. The magnitude and depth of color both increased with the frequency. At the time of greatest frequency more than a quarter of them were of the first magnitude or brighter, and more than a score were seen whose magnitude, length of path, and general appearance were magnificent.

"Veröffentlichungen des Königlichen Astronomischen Rechen-Instituts zu Berlin, No. 16," has been issued recently. The title is "Tabellen zur Geschichte und Statistik der kleinen Planeten," and the work was prepared by Director BAUSCHINGER, with the collaboration of Dr. NEUGEBAUER. The work is arranged in about a dozen tables, and much interesting and useful information is given.

NOVA PERSEI.—In Number 81 of these *Publications* I gave a few notes concerning the progress of our knowledge of the new star in *Perseus*. This wonderful object is still of great interest, and nearly every astronomical journal brings forth an account of some new investigation.

Light Curve.—There is but little to add under this head. The brightness of the star is gradually decreasing. It is now (March 26th) between the eighth and ninth magnitude. Most observers seem to agree that the periodic variation of brightness which was so marked last spring has completely died out. The winter weather in Berkeley, however, has been so persistently bad that it has been impossible to make more than a few scattering observations. Dr. WILSON is continuing the collection and publication (in *Popular Astronomy*) of all the magnitude observations that have been made on the star.

Color.—A study of the color of the new star in *Perseus* has led to some interesting results. At greatest brightness, the color of the star was white; as it declined, it passed through yellow, orange, and red. Some observers report that it has a greenish tint now. The most complete investigation of its color has been made, I think, by Herr OSTHOFF, of Cologne, (*A. N.*, No. 3751). He has collected numerous observations — not all — and reduced them to a common scale, that of SCHMIDT. In this system the colors of stars are designated by the numerals 0 to 10 the significance being 0 = white; 1 = yellowish white, etc.; 9 = red, with least touch of yellow; 10 = red. OSTHOFF has plotted his results, and there is almost a complete correspondence between the resulting color-curve and the light-curve. During April and May, when the star showed the greatest variations of brightness, there were corresponding changes in color. At the minima the star was decidedly red, but there was a considerable tinge of yellow in its color at the maxima. For a change of one magnitude in brightness the color changed about 0.8 of a step.

Spectrum. — The spectroscope has provided a large amount of material, but no one as yet has made, as far as I know, a thorough discussion of it. This is, without doubt, a rich field for study, and it is to be hoped that some one will take it up soon. The changes in the spectrum are fully as interesting as those in the brightness and color. On the date of discovery the spectrum was continuous, with a few dark lines, but by February 25th there were both bright and dark lines. During March and April two distinct types of spectra were observed, called by PICKERING the normal spectrum and the peculiar spectrum, the chief difference between them being that in the normal one the continuous spectrum was very strong, while in the peculiar one the continuous spectrum was rather weak, and a few bright lines were very prominent, which, perhaps, was due to a fading out of the weaker lines rather than to any increased brilliancy of the brighter lines. H_β, H_γ, and H_δ were among the most prominent of the brightest lines. This peculiar spectrum has been called a gas spectrum. PICKERING and VON GOTHARD have found that the so-called normal spectrum was always seen at the time of the star's maximum of brightness and the peculiar (or gas) spectrum at the time of the minimum of light. SIDGREAVES finds, however, from a discussion of the observations made at Stonyhurst and at Oxford, that the changes of the spectrum follow not the phases of the light curve, but the absolute magnitudes of the star's brightness. He found that the peculiar spectrum always appeared when the brightness was less than 4.57 magnitude, and that the normal spectrum always returned when the magnitude became greater than 4.57. One spectrogram, taken when the magnitude was just 4.57 gave a spectrum showing some of the characteristics of both the normal and the peculiar spectra. In June or July the spectrum changed again, and then showed the characteristic lines of a planetary nebula. It has remained of that same nature since then.

One peculiar thing about the spectrum of *Nova Persei*, as well as of *Nova Aurigæ*, is that each bright hydrogen line is accompanied on the side toward the violet by a dark companion line. The interpretation given in 1892 was based upon DOPPLER's well-known principle; that is, that we were observing two bodies, one giving a bright-line spectrum, the other a dark-line spectrum, and the one was moving toward us and the other away from us. The displacement of the lines, however, was large and velocities from 1,000 to 1,500 kilometers per second were necessary in this explanation. This state of affairs might subsist for a few days, but hardly for several months, as was observed in the *Nova Aurigæ*. Two other new stars discovered subsequent to *Nova Aurigæ* exhibited the same kind of spectra, and the new star of 1600, *P. Cygni*, which is still visible as a faint star, showed upon investigation the same spectrum also. Other explanations are now offered, and one of the most rational of these seems to be that proposed by Professor WILSING, of Potsdam. HUMPHREY and MOHLER found from laboratory experiments that the wave-length of a line could be changed by pressure. They were able to employ pressures of twelve atmospheres, but the displacement was very slight. WILSING was able to obtain much greater pressure by utilizing the disruptive discharge between metallic electrodes in water, which occurred with explosive violence and caused a rise of several hundred atmospheres in the pressure of the spark. In this way he was able to obtain displacements comparable with those found in new stars. WILSING and VOGEL have explained the conditions of a star necessary to give these great pressures. (See *Sitzungsberichte der k. Akademie der Wissenschaften zu Berlin*, May and July, 1899; also, *Astrophysical Journal*, Vol. X, pp. 113, 269; Vol. XIII, p. 217.)

Parallax.—No definitive determination of the parallax of the *Nova* has yet been made. Such as have been made, however, show that it must be exceedingly small, and Professor KAPTEYN thinks that it cannot be over one or two hundredths of a second of arc.

Nebulosity.—Several theories have been offered to explain the motions discovered by PERRINE in the nebula about the *Nova*. If we think that there has been an actual displacement of matter, and admit that the parallax does not exceed one or two hundredths of a second, then velocities comparable with those of light are necessary to explain the observed displacements. This is hardly conceivable, but not on that account impossible.

Professor KAPTEYN has suggested (*A. N.*, No. 3756) a theory which has been very favorably received by many. He assumes that the nebulosity, which surrounds the star, has no, or only very little, light of its own, and explains that the effect observed on the photographic plate is that of reflected light from the star itself. When the star first broke forth into great brilliancy, the nebulosity lying nearest to the star would, of course, be made visible first; and as the light-waves traveled outward new portions would be made visible. At the same time, however, as the brilliancy of the star began to decrease, the inner portions of the nebula would become less brilliant or entirely invisible. We would then have portions of maximum brilliancy apparently traveling outward.

The chief source of difficulty with this explanation, according to KAPTEYN, is, will this reflected light be strong enough to affect a photographic plate? This question was fortunately soon answered by Professor SEELIGER, of Munich, (*A. N.*, No. 3759,) who explains that his investigations have led him to almost identically the same conclusions as were reached by KAPTEYN. SEELIGER states, also, that he has already investigated the illumination of a nebula by a star, and he applies the criteria to the case in hand. He found that if we had a star and a nebula at a distance such that the parallax were $0''.01$, then a star of the 10.4 magnitude would illuminate the nebulosity to a distance of $10''$, with an intensity, under certain conditions, of 10^{-7} times the brightness of the full Moon. Now, the *Nova* was, at its brightest, about twelve thousand times as bright as a star of the 10.4 magnitude, and SEELIGER finds that that would have been sufficient to illuminate the nebulosity to a distance of 1100". A translation of KAPTEYN'S article is given in *Popular Astronomy*, March, 1902.

Professor WILSING has offered another explanation (*A. N.*, No. 3765). He thinks that we have here a manifestation similar to that exhibited in comets; that is, that the star is possessed of a repulsive force by which rarefied matter is driven off into space, as the matter of a comet is driven off into the tail by a supposed repulsive force of the Sun. The idea that tremendous repulsive or explosive forces may at times be active in a star has been expounded and developed recently by Professor VERY (*American Journal of Science*, January, February, March, 1902.)

S. D. T.

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, ON SATURDAY, NOVEMBER 30, 1901, AT 2 P.M.

President DOLBEER presided. A quorum was present.

The purpose of the meeting being the Fourth Award of the Bruce Gold Medal, the letters received from the Directors of the six nominating Observatories were submitted by the Secretary. After a careful consideration of the recommendations contained in these letters, the selection of the Medalist was made by ballot, and the following certificate of bestowal was signed by all Directors present:—

SAN FRANCISCO, November 30, 1901.

FOURTH AWARD OF THE BRUCE MEDAL.

We, the undersigned Directors of the Astronomical Society of the Pacific, hereby certify, that, in accordance with the Statutes for the bestowal of the Bruce Medal, a special meeting of the Board of Directors was held this day, at two o'clock P.M., for the purpose of awarding the medal for the year 1902; and that, the provisions of the Statutes relating to its bestowal having been complied with, the medal was awarded to—

G. V. SCHIAPARELLI,

for Distinguished Services to Astronomy, by the consenting votes of eleven Directors.

Signed: JOHN DOLBEER, W. W. CAMPBELL,* CHAS. S. CUSHING. A. H. BABCOCK, CHAS. B HILL,* S. D. TOWNLEY,* E. J. MOLERA,* ROSE O'HALLORAN, C. D. PERRINE,* WM. M. PIERSON, F. R. ZIEL.

(* By proxy.)

Adjourned.

In answer to a letter addressed to Professor SCHIAPARELLI, notifying him of the action taken by the Directors, the following letter of acceptance was received:—

(TRANSLATION.)

MILAN, January 31, 1902

Honorable Sir: Please accept my sincere thanks for your letter of January 1st, containing the announcement that the Astronomical Society of the Pacific has bestowed upon me its gold medal. I hold this a very great honor, which I prize the more as my name is thus added to the list of other eminent astronomers for whom I have the highest admiration. I beg you, Honorable Secretary, to express my profound gratitude to the Astronomical Society of the Pacific and its Directors.

With great and sincere regards, I am, yours devotedly,

G. SCHIAPARELLI,
Milan Observatory.

To the Secretary of the Astronomical Society of the Pacific,
San Francisco.

MINUTES OF THE SPECIAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN HEARST HALL, AT BERKELEY, ON FRIDAY EVENING, FEBRUARY 21, 1902, AT 8 P.M.

The meeting was called to order by Vice-President TOWNLEY.

The chairman announced that the Bruce Medal for the year 1902 had been awarded to Professor G. V. SCHIAPARELLI, of Milan, and that the reasons for the award would be given by the President in his address at the annual meeting in March. He also informed the members that the sum of $500 had been bequeathed to the Society by the last will of the late Mr. MORRIS REIMAN, of Chicago, who had been an active member of the Society for many years. He then introduced the lecturer of the evening.

Dr. W. W. CAMPBELL, Director of the Lick Observatory, gave an account of the meeting of the Astronomical and Astrophysical Society of America, recently held in Washington, which he attended as the representative of the University of California. After giving a summary of the papers presented and of the conclusions arrived at by the subsequent discussions of some of the subjects, he exhibited a large number of beautiful transparencies on glass, representing the photographic work done at the Lick Observatory in recent years.

The meeting then adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, MARCH 29, 1902, at 7:30 P.M.

Mr. DOLBEER presided. A quorum was present. The minutes of the last meeting were read and approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED MARCH 29, 1902.

Mr. JOHN PATTEN . . . . 28-40 S. Front St., Baltimore, Md.

The Secretary reported that, in order to comply with a recent ruling of the Post Office Department regarding second-class mail privileges, it has become necessary to discontinue the printing of advertisements in the *Publications*.

It was, upon motion, resolved that the printing of advertisements be discontinued.

MINUTES OF THE ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, MARCH 29, 1902, AT 8 P.M.

The meeting was called to order by President DOLBEER. A quorum was present. The minutes of the last meeting were approved. The Secretary read the names of new members duly elected at the Directors' meeting.

The following papers were presented:—

1. Address of the retiring President, by JOHN DOLBEER.
2. Reports of Committees: on Nominations; on the Comet-Medal; on Auditing; and Annual Report of the Treasurer.
3. Astronomical Observations in 1901, by TORVALD KÖHL.
4. Planetary Phenomena for May and June, 1902, by MALCOLM MCNEILL.

The Committee on Nominations reported a list of names proposed for election as Directors, as follows: Messrs. R. G. AITKEN, A. H. BABCOCK, W. W. CAMPBELL, CHAS. S. CUSHING, A. O. LEUSCHNER, E. J. MOLERA, Miss R. O'HALLORAN, Messrs. C. D. PERRINE, WM. M. PIERSON, S. D. TOWNLEY, F. R. ZIEL.

For Committee on Publication: Messrs. R. G. AITKEN (Chairman), J. D. GALLOWAY, FRANK SCHLESINGER.

Messrs. RICHARDSON and BRASCH were appointed as tellers. The polls were open from 8:15 to 9 P.M., and the persons above named were duly elected to serve for the ensuing year.

REPORT OF THE COMMITTEE ON THE COMET-MEDAL, SUBMITTED APRIL 1, 1902.

This report relates to the calendar year 1901. The comets of 1901 have been:—

Comet *a* (unexpected comet) discovered April 23d, at Queenstown, South Africa, the name of the first discoverer being as yet unknown. The comet was a conspicuous object, and was independently discovered by many persons in the Southern Hemisphere. The Comet-Medal has not yet been awarded.

Comet *b* (ENCKE'S periodic comet) was rediscovered on August 5th, by Dr. H. C. WILSON, of Goodsell Observatory, Northfield, Minn.

Respectfully submitted,

W. W. CAMPBELL (*ex-officio*),
WM. M. PIERSON,
CHAS. BURCKHALTER,
The Committee on the Comet-Medal.

The Treasurer submitted his Annual Report as follows:—

ANNUAL STATEMENT OF THE RECEIPTS AND EXPENDITURES OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE FISCAL YEAR ENDING MARCH 29, 1902.

GENERAL FUND.

Receipts.

Cash Balance, March 31, 1901		$71 19
Received from dues	$ 991 92	
" " sale of publications	112 20	
" " " " stationery	65	
" " advertisements	25 00	
" " Security Savings Bank (interest)	30	
" " Life Membership Fund (interest)	52 01	
" " Lick Observatory, for two cuts 1898 Eclipse	7 00	
" " Donohoe Comet-Medal Fund (postages on medals Nos. 1-40)	20 00	
	$1,209 08	
Less transfer to Life Membership Fund	50 00	1,159 08
		$1,230 27

Expenditures.

For Publications: printing Nos. 78 to 81 of Vol, XIII	$613 65		
" " illustrations	44 45		
		$ 658 10	
Stationery and printing		37 30	
Postages		50 71	
Rent		180 00	
Salary Secretary-Treasurer		180 00	
Expressages		3 50	
Janitor and elevator		2 50	
Gas		1 00	
Taxes		2 44	
Insurance premiums		21 25	
Lecturer's expenses		5 00	
Lantern at lecture		8 50	
Engrossing diplomas		2 50	
Bank exchanges		20	1,153 00
Cash Balance, March 29, 1902			$77 27

LIFE MEMBERSHIP FUND.

Cash Balance, March 31, 1901	$1,603 95
Received from General Fund	50 00
Interest for 1901	52 01
	$1,705 96
Less transfer to General Fund (interest)	52 01
Cash Balance, March 29, 1902	$1,653 95

DONOHOE COMET-MEDAL FUND.

Cash Balance, March 31, 1901		$684 13
Interest for 1901		22 34
		$706 47
Less engraving medal No. 40	1 00	
" transfer to General Fund (postages on medals Nos. 1-40)	20 00	21 00
Cash Balance, March 29, 1902		$685 47

BRUCE MEDAL FUND.

Cash Balance, March 31, 1901	$2,577 97
Interest for 1901	78 25
	$2,656 22
February 19, 1902, Remittance to A. Dubois, for one gold medal (fourth award)	102 15
Cash Balance, March 29, 1902	$2,554 07

ALEXANDER MONTGOMERY LIBRARY FUND.

Cash Balance, March 31, 1901		$1,543 26
Interest for 1901		50 13
		$1,593 39
Less expenditures:		
Popular Astronomy, subscription Vol. 10	$ 2 50	
Book-shelves (see resolution, page 85, Vol. XIII)	31 50	34 00
Cash Balance, March 29, 1902		$1,559 39

FUNDS.

Balances on Deposit as follows:

General Fund:		
with Donohoe-Kelly Banking Co	$66 93	
" Security Savings Bank	10 34	
		$77 27
Life Membership Fund:		
with San Francisco Savings Union	$603 95	
" German Savings and Loan Society	450 00	
" Hibernia Savings and Loan Society	600 00	
		$1,653 95
Donohoe Comet-Medal Fund:		
with San Francisco Savings Union	$213 99	
" German Savings and Loan Society	230 61	
" Hibernia Savings and Loan Society	240 87	
		$685 47
Alexander Montgomery Library Fund:		
with San Francisco Savings Union	$507 19	
" German Savings and Loan Society	411 81	
" Hibernia Savings and Loan Society	640 39	
		$1,559 39
Bruce Medal Fund:		
with San Francisco Savings Union	$1,274 58	
" Security Savings Bank	638 34	
" German Savings and Loan Society	641 15	
		$2,554 07
		$6,530 15

SAN FRANCISCO, March 29, 1902.

F. R. ZIEL, *Treasurer.*

Examined and found correct.

CHAS. S. CUSHING, } *Auditing Committee.*
F. H. MCCONNELL, }

The report was, on motion, accepted and filed.

The Committee appointed to audit the Treasurer's accounts reported as follows, and the report was, on motion, accepted and adopted:—

SAN FRANCISCO, CAL., March 29, 1902.

To the President and Members of the Astronomical Society of the Pacific:

GENTLEMEN — Your committee appointed to audit the accounts of the Treasurer for the fiscal year ending March 29, 1902, has, after a careful examination, found the same to be correct. Your committee further reports that the books of the Treasurer were found to be in first-class condition, correctly indicating the status of each of the various funds, and that proper vouchers were on file accounting for all moneys expended.

Respectfully submitted,

CHAS. S. CUSHING, } *Committee.*
F. H. MCCONNELL, }

The President then presented his annual address.

The following resolution was, on motion, adopted:—

Resolved, That all the acts appearing in the minutes of the meetings of the Board of Directors of this Society, as having been done by said Board during the past fiscal year, are here now, by this Society, approved and confirmed.

Adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, MARCH 29, 1902, AT 9:30 P.M.

The new Board of Directors was called to order by Mr. TOWNLEY. A quorum was present. The minutes of the last meeting were approved.

The business in hand being the election of officers and committees for the ensuing year, the following officers and committees, having received a majority of the votes cast, were duly elected:—

President: Mr. C. D. PERRINE.
First Vice-President: Mr. S. D. TOWNLEY.
Second Vice-President: Miss R. O'HALLORAN.
Third Vice-President: Mr. CHAS. S. CUSHING.
Secretaries: Messrs. R. G. AITKEN and F. R. ZIEL.
Treasurer: Mr. F. R. ZIEL.

Committee on the Comet-Medal: Messrs. CAMPBELL (*ex officio*), PIERSON, and BURCKHALTER.

Library Committee: Mr. TOWNLEY, Miss O'HALLORAN, Mr. BRASCH. Mr. TOWNLEY was appointed Librarian.

Finance Committee: Messrs. PIERSON, CUSHING, BABCOCK.

The Committee on Publication is composed of: Messrs. R. G. AITKEN, J. D. GALLOWAY, FRANK SCHLESINGER.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. C. D. PERRINE	*President*
Mr. S. D. TOWNLEY	*First Vice-President*
Miss R. O'HALLORAN	*Second Vice-President*
Mr. CHAS. S. CUSHING	*Third Vice-President*
Mr. R. G. AITKEN Mr. F. R. ZIEL	*Secretaries*
Mr. F. R. ZIEL	*Treasurer*

Board of Directors—Messrs. AITKEN, BABCOCK, CAMPBELL, CUSHING, LEUSCHNER, MOLERA, Miss O'HALLORAN, Messrs. PERRINE, PIERSON, TOWNLEY, ZIEL.

Finance Committee—Messrs. PIERSON, CUSHING, BABCOCK.

Committee on Publication—Messrs. AITKEN, GALLOWAY, SCHLESINGER.

Library Committee—Mr. TOWNLEY, Miss O'HALLORAN, Mr. BRASCH.

Committee on the Comet-Medal—Messrs. CAMPBELL (*ex-officio*), PIERSON, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FELIPE VALLE.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

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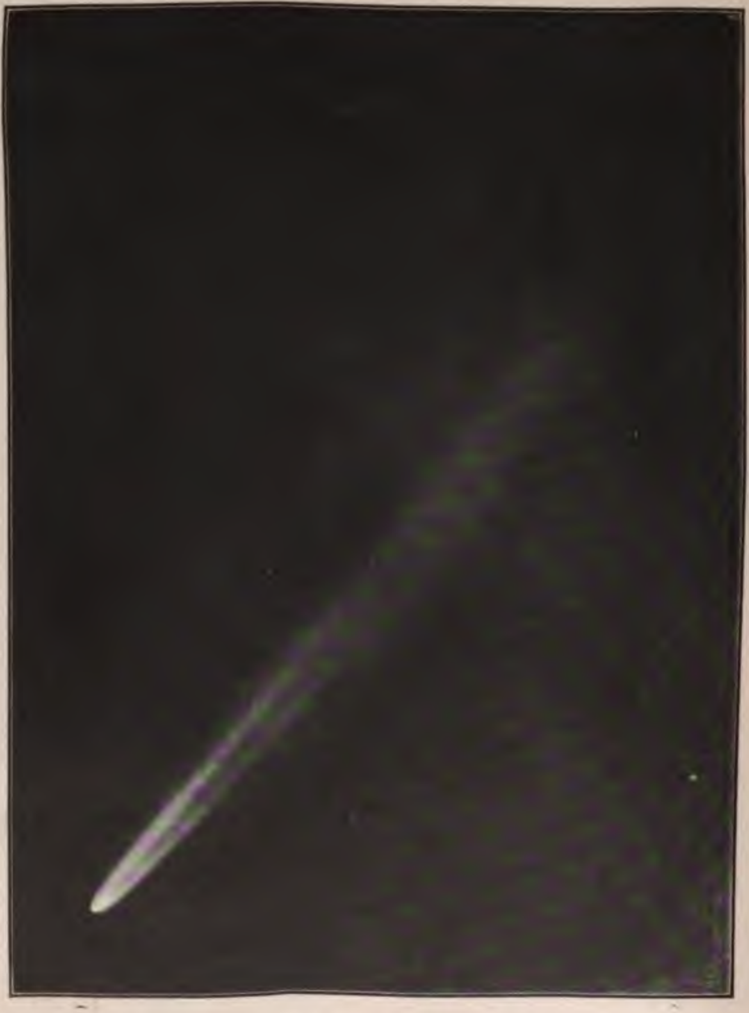

THE GREAT SOUTHERN COMET OF 1901.

From a photograph taken at Padang, May, 1901, by C. D. PERRINE.

THE NEW YORK
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PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

Vol. XIV. San Francisco, California, June 1, 1902. No. 84.

THE FLASH SPECTRUM.

By S. A. Mitchell.

Advances in the "new astronomy" were very rapid after 1859, when Kirchhoff formulated the laws of spectrum analysis. In a communication to the Royal Society, April 23, 1868, Huggins gave the first tangible results in the movements of approach and recession between the Earth and the stars, thus confirming the Doppler-Fizeau principle, announced about a quarter of a century earlier. In the same year, on August 18th, the spectroscope was first applied to a study of the Sun during a total eclipse. We are all of us familiar with Janssen's observations of the spectrum of prominences, with the fact that he saw these "red flames" the next day without an eclipse, with their independent discovery by Lockyer, and with the communication by the two distinguished scientists of their results to the same meeting of the French Academy. These discoveries make a most notable chapter in the history of astrophysics.

Kirchhoff's laws tell us that the dark lines of the solar spectrum are caused by the absorption of light of definite wave-lengths as the rays pass through the metallic vapors that surround the Sun. These vapors are at a high temperature, and if the more intense light of the Sun could be cut off by some means, these gases ought to shine of their own light, and give their spectrum of bright lines. Since these gases cause the absorption spectrum, the lines that appear bright in the emission spectrum ought to have the same positions as the lines that appear dark in the Fraunhofer spectrum, or, in other words, one spectrum is just the "reversal" of the other. Thus reasoned Professor Young. Since the Moon cuts off the light of the Sun at a total eclipse, Professor Young, before the eclipse of

1870, foretold the reversal of the spectrum at the instant the Sun was entirely covered up by the Moon, *i. e.* at the beginning of totality. We can perhaps imagine the feeling of joy experienced by him in having his investigations verified by seeing the bright lines flash out for a few seconds at the beginning and ending of the total phase. Indeed, a great triumph for the mind of man!

But how many of the lines were reversed? It seemed that the flash spectrum matched line for line the Fraunhofer spectrum; certainly the more prominent lines appeared dark in one spectrum and bright in the other; but it was impossible to determine in a few seconds whether *all* the lines of the absorption spectrum were seen also in the emission spectrum, or whether there were any lines in the latter that did not appear in the former. This question could be settled only by obtaining a permanent record of the flash spectrum by photography, which was accomplished for the first time in 1893 by FOWLER, in West Africa, and again in 1896 by SHACKLETON, in Novaya Zembla. From investigations of the photographs of these two eclipses, LOCKYER has found that in the region between F and K only three and eight per cent, respectively, of the lines in the solar spectrum were found in the flash. ("Recent and Coming Eclipses," p. 111.) He also found that the intensities of the lines of the two spectra were by no means the same, and decided, not, indeed, without excellent reasons, that the one spectrum was not the reversal of the other, and that the flash must therefore be due to some other cause than the shining out of the "reversing layer," which, by absorption, causes the Fraunhofer lines. LOCKYER, however, counted the number of lines in the solar spectrum from ROWLAND'S maps, obtained by a much more powerful instrument than had been used at either eclipse,—a test, therefore, which was hardly a fair one.

The differences in intensity of the two spectra were indeed hard to explain. LOCKYER found that certain lines which appeared stronger in the flash than in the solar spectrum also were stronger in the spark than in the arc, and thought that "clearly, then, the chromosphere, as photographed in the eclipses of 1893 and 1896, is a region of high temperature, in which there is a corresponding simplification of spectrum, as compared with the cooler region in which the Fraunhofer absorption is produced" (*loc. cit.*, p. 111); but he does not make perfectly clear how it is that, when we go from the lower layers of the Fraunhofer spectrum *away* from the Sun to the higher region of the flash spectrum, we reach a higher temperature, instead of a cooler one, as we would naturally expect.

The important spectroscopic investigations at the Indian eclipse of 1898 were those of EVERSHED and LOCKYER, both of whom used prismatic cameras. Although the wave-lengths of the flash lines given by the two observers agree very well, the conclusions drawn from them differ as widely as possible. LOCKYER explains the differences of intensity, as he did in the two preceding eclipses, by saying that the Fraunhofer spectrum is connected with the temperature of the arc, while the flash is more nearly related to that of the spark. EVERSHED, on the other hand, accepts YOUNG'S original explanation of the "reversing layer," and gives as the cause of the intensity-variations the *heights* to which the vapors ascend above the Sun's surface.

The cause of these widely different explanations is found in the impossibility of always correctly identifying the flash lines. ROWLAND, by using concave gratings of high dispersion, has given a standard of excellence for the Fraunhofer lines, to which as yet, for the flash spectrum, we have been able to approach only very distantly. Photographs of the flash have been taken with a much smaller dispersion than that of ROWLAND'S maps, with the focus at times none too exact, so that it is not at all surprising that individual flash lines have been assigned by different observers to different elements. It is only through better determination of wave-lengths that we will arrive at the correct interpretation of the solar phenomena.

The only results of the eclipse of 1900 so far published are those of FROST (*Astrophysical Journal,* Vol. 12, 307-351, 1900). His investigations do not show to him any foundation for the stress LOCKYER places on "enhanced" lines in connection with the flash, but, on the other hand, lead him to again confirm YOUNG'S investigations.

In view of these problems of great interest to astronomers, it was with great pleasure that the writer accepted the invitation to become a member of the expedition sent out by the U. S. Naval Observatory to view the Sumatra eclipse of May 18, 1901. The party consisted of eleven—six members of the observatory staff and five invited guests. The former included Professor A. N. SKINNER, U. S. N., in charge of the expedition; Professor W. S. EICHELBERGER, U. S. N.; Professor F. B. LITTELL, U. S. N.; Mr. G. H. PETERS, Mr. W. W. DINWIDDIE, and Mr. L. E. JEWELL, now of the Johns Hopkins University. The guests of the party were Professor E. E. BARNARD, of Yerkes Observatory; Dr. W. J. HUMPHREYS and Mr. H. D. CURTIS, of the University of Virginia; Dr. N. E. GILBERT, of Hobart College; and the writer.

A second party, from the Smithsonian Institution, consisting of Professor C. G. ABBOT and his assistant, Mr. P. A. DRAPER, accompanied the Naval Observatory members, the two parties sailing together from San Francisco on February 16th. Government steamers carried the expeditions to their destination, —the United States army transport " Sheridan " via Honolulu to Manila, the United States steamer "General Alava" from Manila to Sumatra, which was reached April 4th.

Before arriving in the island it had been decided to occupy two stations for observations on the eclipse; one, Solok, near the central line of totality; the other, Fort de Kock, near the northern edge of the Moon's shadow-path.

When we arrived in the East Indies it was soon found that clouds were likely to be exceedingly troublesome, for at no time during the day was the sky perfectly clear. In view of this, it was thought best to subdivide the party at Solok, and a third station was selected at Sawah Loento, twenty miles beyond Solok, at the terminus of the " Staatsspoorweg op Sumatra," the government railroad running inland from Padang. At Sawah Loento were already located Mr. and Mrs. H. F. NEWALL, of Cambridge, England, and a party from the Massachusetts Institute of Technology, under the direction of Professor BURTON.

The eclipse station was situated 1,250 feet above sea-level, the latitude and longitude being:—

$$0^\circ\ 41'\ 52''\ \text{South},$$
$$100^\circ\ 46'\ 40''\ \text{or}\ 6^h\ 43^m\ 6^s.7\ \text{East}.$$

The duration of totality was calculated at five minutes and forty-one seconds.

The main work at Sawah Loento was spectroscopic. The spectroscope consisted of a Rowland flat grating of 15,000 lines per inch, having a ruled surface of 3½×5 inches, and a quartz lens of 3⅜ inches aperture and 72 inches focal length, made by BRASHEAR, the whole apparatus belonging to the Naval Observatory. The grating was employed in the manner which gives a normal spectrum, which is the case when the diffracted ray leaves the grating perpendicularly, or the angle of diffraction is zero. The attempt was made to photograph the first order spectrum from λ 3000 to λ 6000, hence with λ 4500 at the center of the plates.

The day of the eclipse dawned clear, and our hopes were that these favorable conditions would remain till after totality, which occurred shortly after noon. First contact was observed in a perfectly cloudless sky, but soon after this clouds began to gather, and a quarter of an hour before second contact the sky was completely overcast.

The disappearing crescent of the Sun was watched by a binocular, before one half of which was arranged a small plane grating in such a way that with one eye the spectrum could be seen, with the other the Sun itself. With this, shortly before the time of second contact, bright lines were seen for a few seconds at F and H and in several places in the green and yellow, but these disappeared almost immediately,—the Sun being completely hidden by clouds,—and the first flash passed without our being able to see it.

Towards the middle of totality conditions became a trifle better, so that it was possible to see, through clouds, the corona extending for about half a diameter from the Sun, and with the small spectroscope the "coronium" line could be seen quite distinctly. During no time of the five minutes and forty-one seconds of totality was an unclouded view of the corona obtained, but, nevertheless, the second flash was seen beautifully. An hour after the total phase the clouds cleared away, and a perfect sky remained for the rest of the day.

Altogether eight plates—or, rather, films—were exposed, —one before and one just after totality for the cusp spectrum, one at first and one at second flash, and four during the total phase, with exposures of 12^s, 120^s, 90^s, and 45^s, respectively.

The first plate was taken ten seconds before the computed time of the second contact, and was exposed for one half second. It shows the cusp spectrum and about sixty lines between F and H.

As noted above, the clouds thickened at an inopportune time, with the result that nothing appears on the plate exposed for the flash. The four plates exposed during totality show continuous spectrum of a width equal to the diameter of the Sun, and extending from about λ 4900 to λ 3400, also bright lines of hydrogen from $H\beta$ to $H\eta$ and the helium line λ 4471.6 undoubtedly due to the upper chromosphere.

The second flash seemed fully exposed in spite of the clouds.

An exposure was made as soon after totality as possible,—probably five seconds after third contact,—for the cusp spectrum. An exposure of one half second was given, the plate closely resembling that made before second contact.

For some reason the spectra were not all of them in perfect focus. As absorption lines suffer from this defect more than bright lines, it was found practically impossible to measure the cusp spectra. For wave-lengths, we are therefore confined to one plate,—that of the second flash. This was exposed for three seconds, the exposure being stopped at the first reappearance of the Sun.

The peculiarities of this photograph of the flash are twofold: (1) The normal spectrum, and (2) the great dispersion.

On the plate the distance from F to H is 95.4^{mm}, and as the spectrum is normal, 1^{mm} therefore corresponds to a difference of wave-length of 9.37 tenth-meters, or 1 tenth-meter corresponds to a dispersion of about 0.1^{mm}. This dispersion is about one fifth of that obtained with the ordinary Rowland mounting with a grating of 20,000 lines and radius of 21½ feet.

The plate was measured with one of the Repsold machines belonging to the Columbia University Observatory, by comparing the position of the spectrum lines directly with a millimeter scale. Measures with this machine can be made directly to 0.005^{mm}, and by estimation to 0.0005^{mm}, *i. e.* to 0.005 λ; the sharpness of the lines, however, did not permit them to be carried to quite this degree of exactness.

Although the spectrum was not in the most perfect focus, in view of the great dispersion measures could be made with a high degree of accuracy. Wave-lengths were determined by taking well-defined standards properly distributed, whose wave-lengths were taken from ROWLAND's table of standard wave-lengths. Three independent measures of the plate were made.

Second and third contacts were not 180° apart, and the instrument was set up to make a compromise between the two positions. This is the reason for the inclination of the lines of the flash.

Those who have attempted to identify the bright lines with ROWLAND's map know the difficulty of this undertaking. Great care was exercised in the determinations of the wave-lengths, and in the comparisons with ROWLAND's tables. For the flash an arbitrary scale of intensities was taken, where 0 means a line seen with certainty, 10 the strongest line, 00 denotes a line seen with difficulty.

In comparing wave-lengths of the flash spectrum with those of the solar spectrum, it is necessary to bear in mind two points: first, we are dealing with a dispersion of about one fifth of ROWLAND's, with the focus not so exact, and therefore it will be impossible to separate in the flash the counterparts of close dark solar lines; second, the emission and absorption lines are formed at different heights above the Sun's surface, and the emission lines will, as a result, be shifted (in this flash) towards the violet.

The focus is best between F and H, and for the present purpose this region only will be considered. Neglecting *H* and *He* lines and those lines identified with groups, 374 lines were measured in the flash between F and H. Ninety-one of these were unidentified, and 283 were identified with lines in the solar spectrum.

Two points are immediately noticed in comparing the two spectra: first, for each and every element, the brighter the solar line the brighter the flash line corresponding to it; second, the intensities of the solar lines which correspond to a line of given brightness in the flash differ with different metals. *Fe* and *Ni* lines of intensity 5, *Ti, Sc,* and *V* lines of intensity 2 are identified with flash lines of equal strength. These differences for the various elements were so marked that in order to arrive at their significance, and hence draw some conclusions regarding the "reversing layer," comparisons were made between the flash and the solar spectrum.

Although we cannot directly compare the intensities of the bright lines of the flash (scale 0-10) with those of the dark lines given in ROWLAND'S tables (scale 1-1000), we arrive at certain theoretical considerations if we compare the ratios of the average intensities of the different elements,—that is, $\frac{\text{Flash intensities}}{\text{Solar intensities}}$, and also the ratio of the number of lines of each element identified to the whole number of solar lines for that metal. Forming these ratios and arranging them, we are at once struck with the systematic variations not only in the ratio of intensities, but also in the percentage of lines identified.

The meaning of these systematic differences will be understood if we consider these ratios in combination with the atomic weights of the various elements, as is done in the following table, where also are put down the number of lines of the flash due to each metal:—

GROUP I. LINES STRONG IN FLASH AND IN SOLAR SPECTRUM.

Element.	Atomic Weight.	Number of Lines Identified.	$\frac{\text{Intensity Flash.}}{\text{Intensity Solar Lines.}}$	$\frac{\text{Number of Lines Identified.}}{\text{Total Number of Lines.}}$
Na	23.0	—	—	—
Mg	24.3	1	0.10	1.00
Al	27.1	—	—	—
Ca	40.0	8	0.34	0.38
GROUP II. LINES STRONG IN FLASH, WEAK IN SOLAR SPECTRUM.				
Sc	44.1	6	0.81	0.75
Ti	48.1	62	0.68	0.70
V	51.2	15	0.68	0.67
Cr	52.1	38	0.55	0.69
Mn	55.1	27	0.24	0.48
Sr	87.6	2	1.08	0.67
Y	88.7	2	0.50	0.67
Zr	90.6	9	0.46	0.70
GROUP III. LINES WEAK IN FLASH, STRONG IN SOLAR SPECTRUM.				
Fe	56.0	125	0.20	0.32
Ni	58.7	9	0.36	0.28
Co	59.0	6	0.19	0.29

Looking at the numbers in the last two columns, we see that the lines naturally fall into three groups, as given in the above table.

To these may also be added the following lines:—

La, atomic weight 138.5, 3 lines at λ 4123.384, λ 4217.720 and λ 4613.544.
Ba, atomic weight 137, 1 line, at λ 4554.211; and the following lines possibly identified:
Si, atomic weight 12, 1 line, at λ 3905.660.
Zn, atomic weight 65, 1 line, at λ 4810.724.
Ce, atomic weight, 92, 2 lines at λ 4003.912 and λ 4107.649.

In Group I would also fall *Al*, if we consider the relative intensities of the two lines λ 3944.160 and λ 3971.674; and undoubtedly *Na*, if our plate took in the D lines.

The grouping of these lines is exactly that adopted by EVERSHED from his investigations of the Indian eclipse, except that I have put *Zr* with *Sr* and *V* in Group II. *Mn* seems to represent the transition from Group II to Group III.

Sir WILLIAM and Lady HUGGINS* called attention to the great heights to which *Ca* extends in the Sun's atmosphere, and it is on account of this great extent that H and K are such prominent lines, not only in the absorption spectrum, but in the emission spectrum. As EVERSHED† has pointed out, the remarkable variations of the relative intensities in the flash and Fraunhofer spectra are undoubtedly due to the ***heights*** to which the vapors of the different metals ascend in the chromosphere. We would naturally expect that these heights vary according to the atomic weights of the metals, those of least atomic weights ascending to the greatest distances; and, generally speaking, this no doubt is true. But if we have two gases in the Sun's atmosphere,—one a gas with an intrinsic brightness 1 and a layer 100 miles in thickness,—on the photograph there would result a line in the flash spectrum just as bright as for the other gas of intrinsic brightness 100 and only 1 mile thick, if the Sun and Moon were relatively at rest during the period of the "flash"; but considering the gradual advance of the Moon in covering successive layers of the Sun's atmosphere, we see that in the emission spectrum the photographic brightness of the fainter gas would be many times that of the brighter. The absorption caused by a gas depends on the total number of molecules the solar ray comes in contact with, and will be very nearly equal in the two cases.

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* Sir WILLIAM and Lady HUGGINS, "The relative behavior of the H and K lines of the spectrum of calcium," ***Astrophysical Journal***, Vol. 6, 77, 1897.

† EVERSHED, "Wave-length determinations and general results obtained from a detailed examination of spectra photographed at the solar eclipse of January 22, 1898," ***Phil. Trans. Royal Society***, A, Vol. 197, 381-413, 1901.

In view of these considerations, it would therefore seem that the gases of the metals of Group II extend very high, that they are nowhere very much condensed, and that practically all the gas contributes to the formation of the emission line; and hence the flash lines are to be regarded as true reversals of the corresponding solar lines.

The vapors of Groups I and III are somewhat condensed near the Sun's surface (those of Group I, particularly *Ca*, reach far greater heights than those of Group III), but as it is the upper portions that contribute most to the formation of the emission lines, owing to the progressive motion of the Moon, the flash lines are to be regarded as only partial reversals of the Fraunhofer lines, the solar intensities being greater than the flash intensities.

Taking account of lines in the flash identified with groups in the solar spectrum, about half the solar lines have corresponding lines in the flash. From the above considerations, we see that it is highly improbable that lines of intensity 2 on ROWLAND'S scale in the solar spectrum, and belonging to Groups I and III, will have flash lines corresponding to them of sufficient brightness to show in this flash. In fact, although there are 135 *Fe* lines of intensity 2 between F and H, only eleven of these are found in the flash; and, indeed, great numbers of the feebler solar lines are lacking in the flash. But if, on the other hand, we compare the stronger lines, we see that every strong line of the solar spectrum is almost without exception found in the flash spectrum.

And so, remembering the meaning of the differences of intensities, we see no reason for giving up our faith in the existence of the "reversing layer."

We may obtain an approximate estimate of the depths of the layers producing the bright arcs by measuring the angular extent of the arcs. Accordingly, the lengths of some of the more conspicuous bright lines have been measured, and thence were deduced the elevations of the luminous layers producing the bright lines of the flash spectrum. In calculating, the semi-diameter of the Sun was taken as 948″.4, and the Moon's augmented semi-diameter 1013″.8. For the purposes of comparison, the same arcs were taken that Frost* has measured. The depths of the luminous layers of the various metallic vapors come out as follows:—

Spectrum line...	*H* 3970	*He* 4026	*Sr* 4078	*Hδ* 4102	*Sr* 4215	*Ca* 4226	*Sc?* 4247	*Fe pair* 4250	*Cr* 4254
Approximate height of layer	8″	4″	4″	7″	4″	2″.5	2″.5	< ½″	2″.5
Spectrum line...	*Cr* 4274	*Sc* 4321	*Hγ* 4340	*Ti* 4395	*He* 4471	*Ti* 4501	*Ti* 4549	*Ba* 4554	*Hβ* 4861
Approximate height of layer	2″	2″	8″	2″	7″	2″	2″	2.″5	8″

Comparing these heights with the intensities given in my scale (0—10), it is seen that, roughly speaking, the height in seconds of arc is 0.8 of the value of the intensity for Group II, and 0.4 for Groups I and III. The arcs of the great majority of the lines are no longer than the *Fe* pair at λ 4250, which correspond to an extent of ½″.

As a result we may safely infer that the average depth of the "reversing layer" is about 1″, although from the above considerations we see that the heights to which the gases extend and their condensations are different for the different elements.

These results differ materially from those of Sir Norman Lockyer. He lays great stress on the fact that great numbers of "enhanced" lines, or lines stronger in the spark than in the arc spectrum, are found in the spectrum of the chromosphere. In order to investigate this idea, close comparisons were made between the above flash lines and the latest list of "enhanced" lines given by Lockyer in *Proc. R. S.*, Vol. 65, 452, 1900.

Taking up first titanium, as the "enhanced" lines for this metal are most numerous, it is found that he has given fifty-three lines between λ 3900 and λ 4590. This region is all included in the photographs of the flash. Thirty out of the fifty-three "enhanced" lines certainly appear as bright lines in the flash, eleven do not appear, the other twelve are doubtful, from their proximity to strong flash lines, or from their being situated in a group in the flash. Thus 56 per cent of the "enhanced" lines of *Ti* are found as chromosphere lines; and this would seem to strongly support LOCKYER's views. But, on the other hand, every one of these thirty lines, without exception, appears as a strong line in the solar spectrum; and the coincidence between " enhanced " and flash lines does not prove anything definite, for where there are strong Fraunhofer lines we expect strong reversals in the flash. A real test would be the case where there is a strong " enhanced " line, but no strong solar line corresponding to it. Such a line occurs in titanium at λ 4308.60, where the intensity in the spark is 7, and on the same scale in the arc 1-2. There is a line in ROWLAND's tables at λ 4308.601 with an intensity of 00, but there is certainly no exceptionally strong flash line which we would be led to expect if LOCKYER's idea is correct. The appearance of this line may be contrasted with that at λ 4563.94. Both have the same intensity in the spark (*loc. cit.*), but to λ 4563.94 corresponds a strong line of intensity 4 on ROWLAND's scale, and a strong reversal in the flash of intensity 5 on my scale.

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* *Astrophysical Journal*, Vol. 12, 346, 1900.

The conclusions from the " enhanced " lines of iron agree with those for titanium, *i. e.* there are a great number of strong lines in the flash spectrum corresponding to the " enhanced " lines, but they also correspond to strong Fraunhofer lines.

A severe test of the idea that " enhanced " lines are found with great frequency in the spectrum of the chromosphere will be given by the metal vanadium. LOCKYER gives twenty-five lines between λ 3885.05 and λ 4243.10, the majority of which are decidedly stronger in the spark than in the arc. Only four of these lines are with certainty found in the flash, corresponding to LOCKYER's lines at λ 4005.85, λ 4035.80, λ 4225.41, and λ 4243.10. The first two of these have corresponding strong solar lines; the second two have not; none of the four lines, however, are identified by ROWLAND as due to vanadium. Three out of nineteen " enhanced " lines of manganese are found in the flash.

From these comparisons it would seem that there is no close connection between " enhanced " lines and the bright lines of the chromosphere seen in the flash.

When several reasons are advanced to explain the same phenomenon, that one is most readily accepted which is the simplest, which most easily follows the observed facts, and which tends to fewest or no contradictions. Three different explanations are given for the flash spectrum. The first is the original idea of YOUNG's,—that the chromospheric spectrum is merely the flashing out of the reversing layer, the differences of intensities being easily explainable by the different heights to which the layers of the different vapors extend above the Sun's surface. The prominence of "enhanced" lines in the flash spectrum does not seem to be quite as pronounced, from the above investigations, as LOCKYER would have us believe, and there seems, therefore, no solid foundation for the idea that the flash spectrum is at a higher temperature than that of the Fraunhofer spectrum, even if it is farther away than the "reversing layer" from the hot Sun towards the cold of interstellar space. The difficulties in the way of accepting the explanation of JULIUS, as given in the *Astrophysical Journal* for February, 1902, are that we so far have been able to find in the laboratory anomalous dispersion for only one metal, sodium, (although this does not say it may not be found for others); that no photographs have shown the doubling of the lines in the flash spectrum, except those of the Dutch party at the Sumatra eclipse, and that the doubling, if seen, could be so much more easily explained from the lack of perfect focus.

Taking all things into consideration, it seems much easier to explain the flash spectrum, as did Professor YOUNG, as a reversal of the Fraunhofer spectrum.

COLUMBIA UNIVERSITY, May 15, 1902.

SOME NEW ASTRONOMICAL INSTRUMENTS.

BY FRANK SCHLESINGER.

I. THE REGISTERING MICROMETER.—The greatest obstacle in the way of more accurate determinations of Right Ascensions is the observer's personal equation, which causes him to estimate the time of a star's transit always too early or always too late. Were the personal equation constant for each observer for a reasonably long period, things would not be so bad; but it has been known to vary in the course of a single night, besides depending upon the brightness of the observed object, and even upon the steadiness of the atmosphere. REPSOLD, the head of the famous firm of instrument-makers of that name, has constructed an instrument, called the registering micrometer, which is intended to do away entirely with personal equation. Instead of the ordinary reticule seen in the eye-piece of a transit instrument, the registering micrometer has a single movable thread, which the observer sets upon the star as soon as it appears; and he keeps the image constantly bisected (during the minute or so that it takes the star to traverse the field) by steadily turning the screw to which the thread is attached. This screw is so constructed that it automatically records a signal upon a chronograph sheet every time it completes a turn, or even more often, if desired.

This micrometer has been tested by Dr. ALBRECHT and three others of the staff of the Potsdam Geodetic Institute. The differences of personal equation between each pair of these observers were first determined with the ordinary reticule and then with the new micrometer, with these results:—

DIFFERENCES OF PERSONAL EQUATIONS.

			With Ordinary Reticule.	With Registering Micrometer.
ALBRECHT	*minus*	BORASS	$-0^{s}.108$	$-0^{s}.004$
ALBRECHT	"	GALLE	-0.314	-0.035
ALBRECHT	"	SCHNAUDER	-0.184	-0.027
BORASS	"	GALLE	-0.225	$+0.013$
BORASS	"	SCHNAUDER	-0.086	-0.023
GALLE	"	SCHNAUDER	$+0.109$	-0.006

It will thus be seen that the personal equation is gotten rid of, or at least is nearly the same for all observers. Dr. ALBRECHT also finds that the instrumental constants (collimation, flexure, etc.) can be more accurately determined with the new micrometer. In conjunction with Dr. BORASS he has determined the difference of longitude between Potsdam and Bucharest, and between Potsdam and the Poulkova Observatory. The results show surprisingly small probable errors.

A still further improvement has been made by providing the micrometer with clockwork to move the thread across the field. As the rates with which stars apparently move are different in various parts of the sky (those nearest the equator moving fastest), the clockwork must be adjustable to the declination of the star. The observer bisects the image as soon as it appears and then sets the clockwork going. The thread will now approximately bisect the image during the whole of its transit. It will not do so exactly, because of the unsteadiness of the atmosphere and because of irregularities in the clockwork itself; these the observer must counteract by hand, turning the screw slightly to and fro. This arrangement has been tried by the astronomers at Königsberg, by whom also it was devised. As might be expected, the addition of the clockwork has added to the already great accuracy of the instrument.

It is interesting to note that the registering micrometer with clockwork was proposed as early as 1865 by CARL BRAUN, of Kalocsa, Hungary, but his paper on the subject does not seem to have met with the appreciation it deserved.

II. A NEW SHELTER FOR MERIDIAN INSTRUMENTS.—The registering micrometer is intended to improve Right Ascensions. It is in place here to mention a simple expedient by which it is hoped to get better determinations of the Declinations of stars. The importance of the temperature of the observing-room is attracting more and more attention,* and the desirability of open air observations has been pointed out. Three years ago, with this in view, the International Latitude Observatories (in latitude 39° 8′) were built with roofs which could be rolled entirely away from the instruments beneath. In erecting the new meridian-circle at the Cape of Good Hope, Dr. GILL has gone even further. The shelter for the instrument is of steel, and is built of two entirely separate parts, which meet in the meridian. When ready to observe, the two halves are rolled away from each other (the one east and the other west) by means of a small electric motor, and the instrument is thus left actually in the open air.

III. AUTOMATIC HEATING APPARATUS FOR SPECTROGRAPHS.—Another example in which temperature is of the first importance is afforded by spectroscopic observations for motion in the line of sight. The photographic exposures for this purpose sometimes last an hour or more. If the temperature of the prisms changes much in this time, their indexes of refraction also change, and consequently the lines in the spectrum become broad and ill-defined. The first to use artificial means to maintain the prisms at a constant temperature was Deslandres, of the Meudon Observatory. He inclosed the whole prism-box in a tight compartment and allowed water at a constant temperature to flow through it. A much less cumbersome device was that of Lord, of the McMillin Observatory, Columbus, who was the first to use electric heating. He encased the spectroscope in a wooden box, and so placed a thermometer that its bulb was near the prisms, while its graduated tube projected not only outside of the metallic box containing the prisms, but also outside the outer wooden box. It was not necessary, therefore, to remove the latter in order to read the temperature at the prisms. The wooden box was lined with a quantity of German-silver wire. As this substance is not a good conductor of electricity, it will become slightly heated when a mild current is passed through it. The observer watches the projecting thermometer, and if the temperature falls, he turns on the current long enough to bring it back to its original point. A simple improvement upon this arrangement was made by Campbell. The bulb of the thermometer was placed outside of the prism-box, but still within the wooden box. By controlling the temperature in this region, the prisms themselves will really have a more even temperature than in the former arrangement. The idea of providing a thermostat which would automatically control the temperature of the prisms seems to have suggested itself to several observers. Dr. Hartmann, has carried out this idea in connection with the new telescope at Potsdam in an especially ingenious manner. Into the open end of a thermometer-tube is inserted a platinum wire so arranged that its end may be set at any desired reading of the temperature scale. Another platinum wire is set permanently into the bulb of the thermometer and is in contact with the mercury. The free ends of these two platinum wires are connected with the opposite poles of a weak electric battery, the circuit also including a small electric magnet. It is clear that there will be a complete circuit only so long as the mercury in the tube remains in contact with the inserted wire,—that is, so long as the temperature does not fall beyond a certain point. When the circuit is broken the magnet releases its armature, and this in turn completes the circuit of the heating current. Thus, as soon as the temperature near the prisms falls, it is at once raised to its original point by the automatic action of the thermostat. Two independent heaters are used,—one on each end of the prism-box,—in order to insure a perfectly uniform temperature of the air surrounding the prisms. The whole spectroscope, including the two thermostats and the two heaters, is, of course, inclosed in a tight wooden box.

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* See, for example, Dr. TOWNLEY'S review of BAUSCHINGER'S "*Untersuchungen über die astronomische Refraction*," in No. 71 of these *Publications*.

IV. WRIGHT'S APPARATUS FOR PHOTOGRAPHING THE COMPARISON SPECTRUM.—The instrument we have just described enables the observer to devote almost all his attention and time to accurate guiding of the telescope. The only interruptions that need be made are for the purpose of photographing a comparison-spectrum (usually the spark-spectrum of iron) in immediate juxtapositon with the star's spectrum. It is generally regarded as desirable to photograph the comparison-spectrum once or twice after the exposure for the star has begun and once or twice before it is quite finished. To do this by the old methods, the observer must stop the exposure on the star, put the sparking apparatus into position, expose the plate to the spark, remove the sparking apparatus and resume the exposure on the star. All this takes considerable time and may possibly disturb the adjustment of the spectroscope. Mr. WRIGHT, of the Lick Observatory, has devised a neat method for introducing the spark-spectrum without stopping the exposure on the star. The middle part of the spectroscope slit is used for admitting the light of the star. On each side of this space is a little prism which reflects the light of a spark placed entirely to one side of the beam of light which comes from the star. Between each prism and its spark a small lens is inserted, so that an image of the spark is formed at the slit, just next to that part which admits the light of the star. In order to photograph the spark-spectrum, the observer simply turns on an electric switch for a few seconds. Mr. WRIGHT'S invention, like the automatic heating apparatus previously described, economizes the observer's time and attention; besides, it lessens the chance of deranging the spectroscope.

V. THE COLOR-SCREEN (for photographing with a visual telescope).—A telescope used for photography must have an objective which is corrected for the blue and violet rays of light, since to these the photographic film is most sensitive. Such a telescope is nearly useless for visual observations, because those rays to which the eye is sensitive, the yellow and the green, are not brought to a focus. On the other hand, a visual telescope (corrected for these latter rays) cannot ordinarily be used for photography. Mr. RITCHEY, of the Yerkes Observatory, has, however, pointed out a simple expedient by which this can be done. Immediately in front of the photographic plate is placed a sheet of plate glass, which is so colored as to be opaque to the blue and violet rays, while allowing the green and yellow to pass through with nearly undiminished intensity. The blue rays are cut out before they can reach the photographic plate, and are not allowed to blur the picture. Furthermore, Mr. RITCHEY uses isochromatic plates (which are much more sensitive to yellow light than ordinary plates), and thus the length of exposure is cut down. Nevertheless, even with isochromatic plates, considerably longer exposures are necessary than if the objective had in the first place been corrected for photography. Mr. RITCHEY has obtained some beautiful large-scale photographs of the Moon and other objects by means of a color-screen and the great visual refractor of the Yerkes Observatory.

VI. THE MEDIAL TELESCOPE.—This is the name applied by the inventor, Professor SCHUPMANN, of Aachen, to a refractor of peculiar construction. The objective of an ordinary refractor consists of two lenses of different densities. This combination is necessary in order to correct for spherical and chromatic aberration. In the medial telescope, however, the objective consists of one lens, and the light which falls upon it passes through uncorrected. Near the eye-piece is placed a somewhat complicated optical system, which not only corrects for spherical and chromatic aberration, but does it better than is possible with the ordinary objective. For, even with two lenses of different densities, it is not possible to correct entirely for chromatic aberration; there is left what opticians call the "secondary spectrum," the effect of which is to make the images somewhat indistinct in even the best of telescopes. With the medial telescope the secondary spectrum is greatly reduced in intensity. A telescope of this description has been built at Urania Observatory, in Berlin; its aperture is thirteen inches and its focal distance is sixteen feet. The secondary spectrum is only one-twentieth as intense as that in an ordinary refractor of these dimensions. It is reported to be of excellent definition and to give surprisingly faultless views of the planets, even under bad atmospheric conditions. By simply turning a small screw, the image of a star may be broadened out into its spectrum with any desired degree of dispersion. The advantages of this instrument are its almost perfect achromatism and its inexpensive construction. Its disadvantages are its small field and the great loss of light which arises from the character of its optical system.

VII. THE STEREOCOMPARATOR.—If we compare two photographs of the same region of the sky,—taken, say, with an interval of half a year,—they will, to all appearances, be counterparts of each other. It is true that each will be somewhat differently distorted by refraction and aberration, and perhaps by a change in the telescope. But all these effects are so small as to be scarcely perceptible, except by exact measurements, besides being gradual and continuous across the area of a plate. It is therefore clear that by comparing two such photographs we may at once detect stars with large parallaxes or large proper motions. Furthermore, if one plate shows an image that on the other plate either does not appear at all, or appears less strongly impressed, we at once suspect that we have to do with a variable or a temporary star.

Many methods for comparing two photographs have been proposed. BARNARD suggested that a *positive* be made of one of them, and that this be put film to film with the other negative. For most stars the black dots on the negative will be covered by the transparent dots on the positive, and those stars for which this coincidence does not occur can be at once detected. PICKERING proposed that one of the plates be exposed with its *glass side* toward the objective of the telescope, and that the other be taken in the ordinary way, with the *film* toward the objective. These may be placed film to film, with the two images of the same star nearly coinciding. Ordinary stars will thus look like double stars of equal components. Variable stars will appear single or of unequal components; and stars of large parallaxes or large proper motions will appear a little more widely double or a little less widely double than other stars. KAPTEYN, in his work for the Cape *Durchmusterung*, faced two ordinary photographs in the same direction, and viewed them through a telescope four and a half feet distant. The further plate was thus seen through the glass and the film of the nearer. TURNER, of Oxford University, proposed that the photographs be projected upon a large screen by means of two stereopticons, so that the images of the same star should nearly coincide. This method, like KAPTEYN's and the one to be described presently, has the advantage of not requiring specially made photographs: the original negative taken in the usual way may be used.

Some of these methods would appear to leave little to be desired. Yet the instrument used by Dr. WOLF, of Heidelberg, and called by him the *Stereocomparator* is even more convenient than any of these. This instrument is essentially nothing more than a stereoscope, that scientific toy with which we are all familiar. One of the photographs to be compared is viewed solely with one eye, and the other photograph solely with the other eye, in such a manner that the mind gets the impression of a single photograph in which the objects appear at definite distances. The first plate having been fixed in its holder, the second, by proper orientation and tilting, may be so adjusted as to give the stereoscopic effect. Only a limited area of each plate can be observed at a time, but without disturbing their adjustment the two plates may be moved together, so that all the parts of the photographs may be successively brought into view. Most, if not all, of the stars on the photograph will appear to lie in a single plane. But if there be present a star which has been shifted relatively to its neighbors by reason of its parallax or its proper motion, such a star will appear to lie either a little in front or a little behind the plane occupied by the other stars. Again, if a star have a fainter image on one plate than on the other, the eye receives an unpleasant shock, slight but unmistakable. By this means, variable or temporary stars are at once recognized. The scientific value of the stereocomparator may be said to be already proven; with its help Dr. WOLF has found two stars in the *Pleiades* which he suspects of large parallax or proper motions, and he has also published a list of ten suspected variables. The latter are all in *Orion*, which, besides the *Pleiades*, is the only region thus far examined. Incidentally, some novel effects may be obtained with the stereo-comparator. *Jupiter*, for example, may be made to appear much nearer than the fixed stars in the same field, with some of his satellites a little in front and some a little behind *Jupiter* himself.

OBSERVATIONS OF VARIABLE STARS.

By Rose O'Halloran.

The following estimates were made under favorable conditions with a four-inch lens, and may be of interest, though the exact dates of maxima and minima were sometimes unavoidably missed on account of clouds or the interference of high buildings.

S Ursæ Majoris.

A maximum of this long-known variable was predicted for April 18, 1901, but seems to have been a few days later.

1901.	April 4.	Equal to *g* of 9th mag.
	April 8.	Ditto.
	April 16.	Ditto.
	April 18.	About 8.7 mag.
	April 25.	Midway between *g* and *d* of 8th mag.

The comparison-stars used are those lettered on the Harvard charts.

V Coronæ.

In his third catalogue, Professor Chandler alludes to the phases of this variable near its maximum, when a magnitude of from 7.2 to 7.7 is usually attained. A maximum was predicted for April 3, 1901, but observations were not obtained until the following dates:—

1901.	April 8.	Of 9th mag.
	April 16.	Of 10th mag.
	April 18.	Ditto.
	April 21.	Ditto.
	April 23.	Ditto.
	April 25.	Dimmer than 10th mag

Its period being 356 days, a maximum was due about March 26th of this year; but on that date it was only of 10th magnitude, or very slightly brighter than the star 5′ south. On March 29th a similar estimate was obtained.

S Tauri.

The maximum of this variable, predicted for January 31st, was observed as follows:—

1901. Dec. 10, 15, 19, 30. }
1902. Jan. 2, 4. } Invisible.
Jan. 7, 10. Of 12th mag.
Jan. 26, 28, 31. } Brighter than the two adjacent stars, and prob-
Feb. 2. } ably of 10th mag.

R Tauri.

The minimum was predicted for December 28, 1901.

1901. Dec. 10, 15, 19, 30. Invisible.
1902. Jan. 2. A star of 12th mag., in the place of the variable, is discernible.
Jan. 4, 7, 10. }
Feb. 2. } Ditto.

W Aurigæ.

1901. Dec. 10, 12, 15, 18, 30. } Brighter than the two stars of 11.5 mag.,
1902. Jan. 2. } with which it forms a triangle.
Jan. 4, 6, 7, 12, 17. Of 11th mag.
Jan. 25, 26, 31. Of nearly 10th mag.

The maximum predicted for March 15th in the *Companion to the Observatory* was unavoidably missed, but no doubt was seen elsewhere.

V Orionis.

Though this orb sometimes attains a magnitude of 8.4, the brightness was probably much less on the 18th of last January, the date of the predicted maximum.

1902. Jan. 4, 6, 7, 8, 10, 12, 15, 16, 19, 26, 27. Of 10.5 mag.
Jan. 28, 29. Of 11th mag.
Jan. 31. }
Feb. 2. } Of 10.5 mag.

The star south preceding, to which attention is called in *Popular Astronomy* for January, 1895, page 217, was of about 12th magnitude on the above dates.

W Lyræ.

This variable seems to have attained its maximum luster some weeks before the 9th of March, for which it was predicted in the *Companion to the Observatory.*

1902. Jan. 11. About half a mag. brighter than n, which is 8.1 mag.
Jan. 20. Equal to n; brighter than a of 8.6 mag.
Jan. 27. Ditto. Morning very clear. W seems yellowish in color.
Feb. 12. Rather brighter than n — what might be classed as two tenths. Distinctly brighter than a.
Feb. 22. Equal to n.
Mar. 13. Dimmer than a, but brighter than g of 10th mag., and equal to p of 9.4 mag.

R Ursæ Majoris.

The maxima of this star vary from 6 to 8.2 magnitude. The recent maximum was due on February 8th.

1902. Jan. 31. Equal to h, but not to g, which seems slightly brighter. Both comparison-stars are classed as of 8th mag.
Feb. 2. Ditto.
Mar. 12. Ditto.
Mar. 14. Decreased to n of 9th mag.
Mar. 24. It is of about 10.3 mag.

L^2 Puppis.

The maximum of this star was due February 28th.

1902. Jan. 31. Brighter than 4th mag., as compared with *Sigma Puppis* of 3.4 and L^1 of 5th mag.
Feb. 12. } Ditto.
Mar. 2, 9. }
Mar. 14. Slightly brighter than *b Puppis*. Classed as of 4.8 mag

SAN FRANCISCO, March 31, 1902.

KAPTEYN'S CONTRIBUTIONS TO OUR KNOWLEDGE OF THE STARS.

By J. D. GALLOWAY.

In commenting on the award of the gold medal of the Royal Astronomical Society to Professor J. C. KAPTEYN for his work in connection with the Cape Photographic *Durchmusterung* and his researches on stellar distribution and parallax, Dr. GLAISHER, the president of the society, gave a brief history of this great photographic catalogue, and referred to some of KAPTEYN's other contributions to stellar cosmography.

The idea of making a photographic star-map was suggested to GILL when experimenting with an ordinary camera in photographing the great comet of 1882. The work for the catalogue was done with a Dallmeyer rapid rectilinear lens of six inches aperture and fifty-four inches focus. Another lens was tried for a time, but found unsatisfactory, and all plates taken with it were discarded; so that the finished work is the product of one lens. Part of the expense was borne by the Government Grant Fund of the Royal Society, part by the Dutch Government, and part by several Dutch institutions. One reason for the withdrawal of the Royal Society from the work was the commencement, in 1887, of the preparation of the International Astrographic Chart. It was thought by some that this would supersede the work of GILL and KAPTEYN; but the belief of Dr. GILL was that there was an immediate use for his work, so it was pressed to a conclusion.

KAPTEYN offered his services to GILL in 1885, stating that he believed he had "enthusiasm for the matter equal to six or seven years of such work." He did not overestimate his enthusiasm, which was to sustain him not only for six or seven years, but for nearly thirteen. KAPTEYN's proposal was that he be allowed to measure the plates taken at the Cape and to tabulate the results. The actual photographing of plates at the Cape began in April, 1885, and was completed at the end of 1890.

The principal object which GILL had in view may be briefly described as the extension of the Bonn *Durchmusterung* to the south pole. To determine the exposure necessary for this purpose, an area in the Bonn *Durchmusterung* was selected and photographed. The negative was then compared star by star with ARGELANDER's chart, and the duration of the trial exposures was gradually increased till it was certain that every star in the selected part of the chart was shown as a measurable disc on the plate photographed from the sky. It may be mentioned that when the negative from the sky showed nearly the whole of ARGELANDER's stars, it also showed a great many more, as the Bonn *Durchmusterung* professes to complete only as far as stars of the 9.2 magnitude. Every area was photographed on two different nights, in order to avoid the possibility of a speck on the plate being mistaken for a star.

KAPTEYN'S work was done at Groningen, Holland, and consisted in the measurements of the stars on the plates, their reductions, and the forming of the catalogue. All the measurements for the catalogue were made by an instrument designed by KAPTEYN for the purpose. The principle of this instrument, the object of which was to measure spherical coördinates from the plate, occurred to him very soon after he had received the first plates. It depends upon the obvious fact that by placing a plate at the proper distance (that is, at the focal distance of the photographic telescope), with the film farthest from the eye, it is possible to cover the stars in the sky with their corresponding images. If, therefore, we substitute for the eye an instrument by which spherical coördinates can be measured in the sky, we can measure these coördinates as well on the plate. Various refinements were used. The work was done in a darkened room by two observers and a clerk. Two plates covering the same region were fixed in the holder, and by adjustment were so placed that the image of a star on one plate nearly covered the image of the same star on the other plate. True stars then appeared double, while accidental specks appeared single, and could at once be distinguished.

Each plate was observed twice, and as soon as the second observation was made the results were compared and discrepancies examined. The second observations and examinations were invariably made by KAPTEYN.

The diameters of the images of the stars were estimated to $2''$ of arc, and from these diameters the magnitudes of the stars were determined by an empirical formula.

The work is published in three volumes, bearing dates of 1896, 1897, and 1900. It includes all stars down to about 9.5 magnitude from —18° to the south pole. The number of stars included is 454,857. The catalogues of ARGELANDER and SCHÖNFELD together contain 431,760 stars for the rest of the sky, the average number per square degree being for the Cape, Argelander and Schönfeld catalogues 32.66, 15.19, and 18.21, respectively, so that the star-density of the Cape catalogue is more than double that of ARGELANDER'S.

As compared with the catalogue of SCHÖNFELD, the star

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density shown by the Cape catalogue varies widely, some regions containing three times the number of stars given by SCHÖNFELD in the same area, while in some regions the latter's catalogue was the richer, containing almost double the number shown on the plates. KAPTEYN also found that, corresponding to these variations in the star-brightness, equal diameters on the plates were produced by stars of unequal brightness in different parts of the sky. THOME suggested that this might be due to a tendency on the part of a visual observer to overlook faint stars in a rich field; but KAPTEYN considers any such explanation quite inadequate, and he concludes that the difference between the visual and the photographic magnitudes is largely due to the positions of the stars with regard to the Milky Way, and that, even if we take into account only stars of the same spectral type, those in the Milky Way are in general bluer than the stars in other regions of the sky.

In 1889 KAPTEYN proposed a comprehensive method of determining stellar parallax, having been engaged in that work when he made his proposal to GILL in 1885. His plan was to expose the plates for the astrographic catalogue at three successive epochs of maximum parallactic displacement, the plates being carefully preserved in the intervals of six months, and developed after the third exposure. The plates would then furnish, in addition to the position of the stars, a first determination of their parallaxes. The proposal was not adopted for the great catalogue, but Professor DONNER obtained a series of plates at Helsingfors which were measured by KAPTEYN and the approximate determinations of the parallaxes of 246 stars were made.

Since the direct determination of stellar parallax has not given results on anything like the scale required for the purpose of judging of the relative distances of the stars, we are compelled to resort for data on this point to the parallactic displacement caused by the motion of the solar system in space. This parallactic motion, however, cannot be separated from the real proper motion for the individual stars, but there is every reason to think that the real proper motion shows but little preference for determinate directions, and it may therefore be assumed that, in the mean results obtained from small groups of stars, these real proper motions will destroy each other, leaving only that part due to solar motion. It is this parallactic displacement that gives the most reliable measure of the mean distances of stars. KAPTEYN has undertaken the resolution of the proper motions of 2,357 stars into components in the apical direction (that is, the direction of the Sun's movement in space), and normal thereto. These stars are in the Draper catalogue of spectra, and are also included in the Bradley-Auwers catalogue of Right Ascensions and Declinations. The stars were taken from the Draper catalogue, because KAPTEYN had decided to divide them into groups according to their spectral type, and to consider the groups separately. This division has shown that stars with small proper motions belong generally to the first type, and those with large proper motions to the second, to which type our own Sun belongs. It may be that the stars of the second type are moving faster than those of the first, but it seems more probable that they are less distant. This gives some support to GOULD's suggestion that the Sun is a member of a star-cluster.

Other important papers of KAPTEYN refer to the distribution of cosmical velocities, the distribution of stars in space, the statistical relations between parallax, proper motion, and magnitude, and upon the luminosity of stars. He has deduced the position of the solar apex by a new method, in which the apex is so chosen that the sum of the proper motions resolved in the direction of the Sun's apex is a maximum, or that the sum of the motions perpendicular to this direction is zero. The resulting apex is $\alpha = 273^\circ.6$, $\delta = 29^\circ.5$ as deduced from 2,640 Bradley stars and 699 Porter stars. The discrepancy from PORTER's results (obtained by KAPTEYN's method), $\alpha = 280^\circ.5$, $\delta = 49^\circ.3$, and from CAMPBELL's result, $\alpha = 277^\circ.5$, $\delta = 20^\circ.0$, derived from spectroscopic determinations of 280 velocities in the line of sight, only shows what might have been expected—that considerable groups of stars in different parts of the sky are affected by common drift which is quite distinct from parallactic motion.

As showing the estimation in which KAPTEYN's work is held, the following is added from NEWCOMB, when writing of the Cape *Durchmusterung:* "This work of KAPTEYN offers a remarkable example of the spirit which animates the born investigator of the heavens. . . . The years of toil devoted to it were, as the writer understands, expended without other compensation than the consciousness of making a noble contribution to knowledge, and the appreciation of his fellow astronomers of this and future generations."

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1902.

By Malcolm McNeill.

July.

The Earth is in aphelion July 4th, 5 A. M. Pacific Time.

Mercury is a morning star, having passed inferior conjunction on June 23d. It reaches greatest west elongation on July 15th, and is well on toward superior conjunction by the end of the month. The conditions for visibility are not very good; but after the first week of the month the planet rises an hour or more before sunrise, and there is a possibility of seeing it in the morning twilight if the air is very clear.

Venus is the chief morning star, and throughout the month rises about two and one-half hours before the Sun. It moves about 35° eastward during the month from a position between the *Pleiades* and *Hyades* in *Taurus* to the middle of the constellation *Gemini*, west and south of *Castor and Pollux*. Its distance from the Sun diminishes about 5°.

Mars is also in the morning sky, but has not begun to brighten up very much. It moves about 20° eastward from the eastern part of *Taurus* into *Gemini*, and toward the close of the month is near *Venus*, a little to the north of the latter.

Jupiter will, at the end of the month, rise a little after sunset, and is therefore in fair position for late evening observation. It is in the eastern part of the constellation *Capricorn*, and is moving westward, the motion being about 3° during the month, and on a line a little south of the line of motion during the spring months.

Saturn comes to opposition with the Sun on July 17th, and is therefore above the horizon practically the entire night, during the month. It is in the western part of the constellation

Capricorn, and it moves a little more than 2° westward. It draws a little nearer *Jupiter,* but hardly enough to be noticeable without measurement. As seen in the telescope, the apparent minor axis of the rings will be much shorter than it was in 1901.

Uranus remains above the horizon until early morning. It moves about 1° westward in the constellation *Ophiuchus* and is, on July 1st, 1½° west and about 2° north of *θ Ophiuchi,* a third-magnitude star in the southern part of the constellation.

Neptune is very close to the Sun, a morning star, having passed conjunction on June 23d.

AUGUST.

Mercury is a morning star at the beginning of the month, rising about an hour before sunrise, but it rapidly nears the Sun and passes superior conjunction on August 11th, becoming an evening star. By the end of the month it has moved far enough away from the Sun to set nearly an hour and a half later; and it can therefore be seen in the evening twilight if the air is clear.

Venus is drawing nearer the Sun, and the time between the rising of the planet and that of the Sun shortens up nearly half an hour. The planet moves about 36° eastward from *Gemini* into *Cancer,* and lessens its distance from the Sun about 8° during the month.

Mars is increasing its apparent distance from the Sun, and by the end of the month rises at about 2 A. M. It moves eastward about 20° in the constellation *Gemini* and during the latter part of the month is south of the principal stars *Castor* and *Pollux,* at about the same distance from the nearer as the stars are from each other. The planet will not be very bright, but can readily be distinguished by its ruddy color. On August 1st *Mars* is in conjunction with *Venus.*

Jupiter comes to opposition on August 5th, and is therefore above the horizon practically the entire night. It is still in *Capricorn* and moves westward rather more than 3°.

Saturn is above the horizon until long after midnight. It is in the western part of *Capricorn* and moves westward about 2°. It approaches *Jupiter* about 2° during the month, their distance apart at the close of the month being about 18°.

Uranus is in the western sky in the evening, but is high enough for convenient observation until quite late. It changes its position only a little during the month, and it may still be found by its nearness to *θ Ophiuchi*. The planet is about a degree farther west of the star than it was on July 1st.

Neptune is farther away from the Sun than during July, but needs a telescope to show it.

JULY–AUGUST, 1902.

PHASES OF THE MOON, P. S. T.

New Moon . . .	July 5,	4^h	59^m	A.M.
First Quarter . . .	July 12,	4	47	
Full Moon . . .	July 20,	8	45	
Last Quarter . . .	July 27,	9	15	P.M.
New Moon . . .	Aug. 3,	12	17	
First Quarter . . .	Aug. 10,	8	24	
Full Moon . . .	Aug. 18,	10	3	
Last Quarter . .	Aug. 26,	3	4	A.M.

THE SUN.

1902.		R. A.	Declination.	Rises.	Transits.	Sets.
July	1,	6^h 38^m	+ 23° 10′	4^h 39^m A.M.	12^h 3^m P.M.	7^h 27^m P.M.
	11,	7 19	+ 22 12	4 45	12 5	7 25
	21,	7 59	+ 20 37	4 53	12 6	7 19
	31,	8 39	+ 18 27	5 1	12 6	7 11
Aug.	10,	9 17	+ 15 47	5 10	12 5	7 0
	20,	9 55	+ 12 41	5 19	12 3	6 47
	30,	10 32	+ 9 15	5 29	12 1	6 33

MERCURY.

July	1,	5 20	+ 18 44	4 5 A.M.	11 16 A.M.	6 22 P.M.
	11,	5 55	+ 19 52	3 30	10 41	5 52
	21,	6 36	+ 21 50	3 24	10 43	6 2
	31,	7 49	+ 21 49	3 58	11 16	6 34
Aug.	10,	9 15	+ 17 47	5 1	12 3 P.M.	7 5
	20,	10 31	+ 10 58	6 1	12 39	7 15
	30,	11 34	+ 3 24	6 52	1 3	7 14

VENUS.

July	1,	3 59	+ 18 38	2 19 A.M.	9 24 A.M.	4 29 P.M.
	11,	4 48	+ 20 46	2 20	9 34	4 48
	21,	5 38	+ 22 9	2 26	9 45	5 4
	31,	6 29	+ 22 32	2 36	9 57	5 18
Aug.	10,	7 21	+ 21 53	2 50	10 9	5 28
	20,	8 13	+ 20 11	3 10	10 21	5 32
	30,	9 3	+ 17 31	3 31	10 32	5 33

Mars.

July	1,	5 3	+23 4	3 6 A.M.	10 29 A.M.	5 52 P.M.
	11,	5 33	+23 41	2 53	10 19	5 45
	21,	6 2	+23 56	2 41	10 9	5 37
	31,	6 32	+23 51	2 32	9 59	5 26
Aug.	10,	7 0	+23 26	2 23	9 48	5 13
	20,	7 28	+22 43	2 15	9 37	4 59
	30,	7 56	+21 43	2 7	9 25	4 43

Jupiter.

July	1,	21 16	−16 43	9 41 P.M.	2 43 A.M.	7 45 A.M.
Aug.	1,	21 2	−17 48	7 30	12 28	5 26
Sept.	1,	20 47	−18 52	5 13	10 6 P.M.	2 59

Saturn.

July	1,	19 51	−21 4	8 33 P.M.	1 18 A.M.	6 3 A.M.
Aug.	1,	19 41	−21 31	6 20	11 3 P.M.	3 46
Sept.	1,	19 34	−21 51	4 12	8 53	1 34

Uranus.

July	1,	17 10	−23 2	5 56 A.M.	10 33 P.M.	3 10 A.M.
Aug.	1,	17 6	−22 57	3 51	8 28	1 5
Sept.	1,	17 5	−22 56	1 48	6 25	11 2 P.M.

Neptune.

July	1,	6 6	+22 21	4 11 A.M.	11 32 A.M.	6 53 P.M.
Aug.	1,	6 11	+22 20	2 14	9 35	4 56
Sept.	1,	6 15	+22 18	12 15	7 36	2 57

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb before August 5, off right-hand limb afterward, as seen in an inverting telescope.)

I, D,	July	1,	1^h 40^m A.M.	I, D,	Aug.	1,	10^h 15^m P.M.
I, D,		2,	8 9 P.M.	I, D,		3,	4 44
II, D,		3,	8 26	I, R,		9,	2 26 A.M.
I, D,		8,	3 34 A.M.	I, R.		10,	8 55 P.M.
I, D,		9,	10 3 P.M.	II, R,		12,	1 29 A.M.
II, D,		10,	11 0	III, R,		12,	4 51 P.M.
III, D,		14,	9 17	I, R,		17,	10 50
I, D,		16,	11 57	I, R,		19,	5 18
II, D,		18,	1 35 A.M.	III, R,		19,	8 51
I, D,		18,	6 26 P.M.	II, R,		22,	5 22
III, D,		21,	1 17 A.M.	I, R,		25,	12 45 A.M.
I, D,		24,	1 52	I, R,		26,	7 13 P.M.
II, D,		25,	4 10	III, R,		27,	12 53 A.M.
I, D,		25,	8 21 P.M.	IV, D,		29,	6 0 P.M.
II, D,		28,	5 27	II, R,		29,	7 58
I, D,		31,	3 47 A.M.	IV, R,		29,	10 43

TWO RECENT VOLUMES OF DOUBLE-STAR MEASURES.[*]

A REVIEW, BY R. G. AITKEN.

We have several times called attention in these *Publications* to the fact that the progress of double-star astronomy in the last few years has been very satisfactory; the well-known binary stars have been followed more carefully than ever before, and their orbits revised and corrected by means of the new measures; old and neglected pairs have been looked up and measured; many new pairs have been discovered; and two of the most important catalogues of double stars—BURNHAM'S and OTTO STRUVE'S[†]—have been published in such form as to put all data relating to the stars they contain in convenient form for study.

But the field is large and the toilers in it even now none too many. Especially do we need all the measures we can get of the closer double stars—those that require large telescopes for their accurate measurement. Such contributions as the two volumes now under consideration are for this reason particularly welcome.

The first one contains the observations of 900 double stars made by Mr. ERIC DOOLITTLE with the new 18-inch telescope of the Flower Observatory, between the dates of January 1, 1897, and October 15, 1900. His observing list comprised "348 β stars, principally those which have not been measured since 1891, or of which, for other reasons, the character of the motion is uncertain; 471 miscellaneous stars, principally neglected pairs of the HERSCHELS and STRUVES, and including those (22) which are believed to be new; 55 stars noted as double in the catalogues of the *A. G.* Zones, 55°-70°, and previously measured by BURNHAM; and 33 stars of the 40 binary stars whose orbits have been computed by Dr. SEE."

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[*] *Publications of the University of Pennsylvania*, Astronomical Series, Vol. I, Part III. Measures of nine hundred Double and Multiple Stars, made with the Eighteen-inch Reefractor of the Flower Astronomical Observatory, by ERIC DOOLITTLE.

Publications de Poulkovo, Série II, Vol. XII. Mikrometer-Messungen von Doppelsternen ausgeführt am 30-zölligen Refractor zu Pulkowa von HERMANN STRUVE.

[†] By W. J. HUSSEY, as Vol. V, *Publications* of the Lick Observatory.

The fact that Mr. Doolittle in selecting his list of stars had the benefit of advice from Mr. Burnham, to whose kindness all of the younger double-star observers owe so much, is in itself sufficient evidence that the work was worth doing; and a study of the measures shows that the work was well done. In general, each star was measured on at least three nights, the more rapid binaries in some cases on as many as fifteen or twenty nights, and great care was exercised to make the separate settings independent and to free the measures as far as possible from systematic errors. The results have been printed in very convenient and neat form, giving the observed data without any superfluous matter.

Professor Struve's volume contains the results of the observations made by him in the period 1885–1895 with the 30-inch telescope at Pulkowa. His working-list during the first year was made up of β stars, which were too difficult for observation with the 15-inch refractor. To those were added in the following year all the Struve and Otto Struve stars which, according to the measures by Struve, Otto Struve, and Dembowski, had given evidence of motion, and also a few other interesting stars. This brought the total number of stars to about 900,—470 Σ stars, 190 OΣ stars, 200 β stars, and 30 miscellaneous pairs. As the telescope was also used for extensive series of satellite measures and for spectroscopic work, the work on this double-star programme was so much interrupted that when Professor Struve left Pulkowa in 1895 measures had been made of but 750 of these pairs. Special attention had been given, however, to the closer pairs and those in rapid motion,—as for example, ζ *Cancri*, ε *Hydræ*, ζ *Herculis*, and δ *Equulei*,—and in all about 3,100 separate measures were made.

Professor Struve devotes the greater part of his introduction to this volume to the discussion of the systematic errors of his observations.

In measuring the angle of pairs separated by 5″ or more, he followed the method of bisecting both stars with a single wire; but the position-angles of the closer pairs were measured by the "usual method,"—that is, by placing the stars midway between two wires slightly separated.

Four settings were generally made, the eyes being kept parallel or perpendicular to the line joining the stars. Double distances were measured, four settings being made ordinarily.

To determine the systematic errors directly, many of the stars were measured repeatedly at different hour-angles and with eyes parallel and perpendicular to the line joining the stars, and measures with a very high power were also compared with those made with the lower-power eye-piece, which was more generally used.

Professor STRUVE concludes that his observations in angle are affected by small systematic errors, which, in the case of angles measured by the "usual method," vary with the hour-angle and the position of the eyes. The position of the fainter star, to the right or left, above or below the primary, also exercises an appreciable effect. The measures made by the method of bisection do not seem to be affected by the hour-angle nor by the position of the eyes. But while the systematic errors seem to be real, they are in all cases small, the final result being that his angle-measures require an average correction of + 0°.42.

This direct investigation is confirmed by comparisons with the measures of W. STRUVE and DEMBOWSKI, which lead to an average correction of + 0°.38.

The comparison of his distance-measures with those of these two observers indicates that his own are practically free from systematic errors.

Professor STRUVE also gives an interesting comparison of his measures of twenty-seven binary stars with the computed positions derived from Dr. SEE's orbits. The table shows the observed positions, the residuals HΣ — computed, and also the residuals (O — C) given by Dr. SEE for the corresponding dates. Dr. STRUVE, for reasons that are readily apparent, does not use this material to determine his systematic errors definitely. But it occurred to me in examining the table that corroborative testimony could be drawn from it by comparing the two columns of residuals. This would give residuals HΣ — O where O indicates the mean of the observed positions as combined by Dr. SEE for the basis of his computations. Assuming these means to be free from systematic error (an assumption not wholly warranted) the residuals will give H. STRUVE's systematic errors. I have made this comparison, and find that the average residual in angle (omitting two abnormal residuals of + 13°.6 and + 16°.4, respectively) is — 0°.32, and in distance + 0″.028. The systematic corrections are therefore + 0°.32 and — 0″.028, results which, so far as their evidence goes, confirm the observer's own conclusions.

Professor STRUVE has also investigated the probable error of his measures dividing the stars into classes according to the measured distances. He finds that the maximum probable error is less than ± 0″.09 in either coördinate,—a result that is very satisfactory.

It is evident from these investigations that the measures possess a high degree of accuracy.

It may perhaps be noted as a matter of some practical interest that both DOOLITTLE and STRUVE differ from the present observers at the Lick Observatory (and, I believe, from BURNHAM and BARNARD also) in their method of measuring the angles of "stars not very far apart." They place the stars midway between two wires separated by a few seconds of arc; we use the method of bisection with a single wire.*

The former method is the one used by practically all the earlier double-star observers, and by many excellent observers at the present time as well; but I am satisfied that better results, —that is, results more likely to be free from systematic error,— are attainable by the latter method, especially if the use of the tangent-screw is dispensed with and the settings are made with the pinion, the wire being moved quickly to either side of the true position a number of times before final adjustment.

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*See Professor HUSSEY's statement, which represents my observing practice as well, in *Publications* Lick Observatory, Vol. V, p. 13.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

THE GREAT SOUTHERN COMET OF 1901.

Shortly before the total eclipse of 1901, May 18th, a very bright comet appeared in the southern sky, being discovered almost simultaneously at a number of places. The first reported sight of it in Sumatra was on May 3d, by Mr. W. W. DINWIDDIE, of the U. S. Naval Observatory expedition at Solok. It was then near the Sun in the evening sky, but very bright and conspicuous even in bright twilight.

The comet was not seen in Padang until the evening of May 5th. It was then brilliant, with a tail 6° or 8° in length, although it is said to have lost much of its light in the interval of two days.

On May 6th, the Pierson-Dallmeyer camera for use at the eclipse was temporarily mounted, and on the same evening four exposures were made. The longest exposure was seven minutes, and recorded the tail to a distance of 4°.

The accompanying illustration is from the second negative obtained, with an exposure of three minutes, and is enlarged two diameters. The tail on this plate is shown to a distance of 3½°, and a second very faint streamer is to be seen to the south, making an angle of about 35° with the principal tail. The principal tail appears to be of the hollow cylindrical type usually seen in the case of large comets, especially those making a near approach to the Sun.

The nucleus of the comet and the star-images are seen elongated, owing to the lack of means to correct for the varying refraction and the irregularities of the driving clock.

C. D. PERRINE.

MT. HAMILTON, CALIFORNIA, 1902, May 15.

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* Lick Astronomical Department of the University of California.

NOTE ON COMET BROOKS.

The telegram announcing the discovery of a comet by Dr. W. R. BROOKS was received here on the morning of April 16th. It was observed the following morning (Thursday) with the 12-inch telescope, and was found to be a rather bright telescopic object. By comparison with neighboring stars, its light was estimated as about equal to that of a star of 8.5 magnitude. A straight tail could be traced fully half a degree, in position-angle 295°.5 (April 16 at 16^h 5^m, Mt. Hamilton M. T.) or directly away from the Sun. The condensation in the head of the comet was well defined, but there was no stellar nucleus.

On the following morning the sky was cloudy, but the comet was seen twice at intervals of nearly five minutes, and each time for only a few seconds. Advantage was taken of these glimpses to make one setting each in R. A. and Decl. Owing to continued bad weather, the comet has not been seen here since. As the comet was rapidly approaching the Sun, and as no observations were received here for dates later than April 16th, I used the Koenigsberg and Mt. Hamilton observations of that date (the time interval between them being about 10½ hours) and the incomplete observations of the 17th to derive an approximate set of elements, with the following result:—

$$
\begin{aligned}
T &= \text{May } 6.82 \\
\omega &= 226^\circ\ 13' \\
\Omega &= 51\ \ \ 31 \\
i &= 68\ \ \ 18 \\
\text{Natural } q &= 0.4643.
\end{aligned}
$$

Because of the uncertainty of the third observation, these elements were considered as merely a rough approximation, but it will be seen that they are in close agreement with those cabled later on from Kiel,* which were based on observations made in Europe on April 16th, 17th, and 18th. They show that the comet will not be visible to observers in the northern hemisphere for several months. By that time it will be so far from the Earth and Sun that it is very doubtful whether it will be bright enough to be seen. It is to be hoped that observers in the southern hemisphere have been more fortunate in securing measures of this comet than those in Europe and America.

May 14, 1902. R. G. AITKEN.

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* See Astronomical telegrams, on another page of this number.

MEASURES OF THE COMPANION OF *SIRIUS.*

During the present season I have obtained the following measures of the companion of *Sirius* with the thirty-six-inch refractor:—

1901.853	129°.2	5″.30
1902.237	127 .8	5 .32
.239	127 .6	5 .57
.241	126 .3	5 .58
.252	126 .4	5 .49
.255	125 .2	5 .48
1902.18	127°.1	5″.46

The interpolated place of the companion for the mean date from ZWIERS's ephemeris is 125°.3, 5″.48.

W. H. HUSSEY.

MEASURES OF THE COMPANION TO *SIRIUS.*

The following measures of the companion to *Sirius* were made with the 36-inch telescope, using an eye-piece with a power of 520. The observing conditions were most favorable on the second night. On the last night the seeing was poor, and measures were made with difficulty:—

	θ	ρ	Sid. Time.
1902.238	127°.5	5″.50	8^h.0
.241	126 .0	5 .46	7 .0
.252	129 .5	5 .51	8 .3
1902.24	127°.7	5″.49	

ZWIERS's orbit gives the position for 1902.24 as 124°.8, 5″.51.

May 15, 1902. R. G. AITKEN.

PERSONAL NOTES.

Dr. W. W. CAMPBELL, Director of the Lick Observatory, was elected to membership in the National Academy of Sciences at the last annual meeting, held in Washington, D. C., on April 17th.

Dr. S. D. TOWNLEY, of the Astronomical Department at Berkeley, will spend the summer vacation at the Lick Observatory, devoting his time to the observation of variable stars and to other photometric work.

ASTRONOMICAL TELEGRAMS.

(*Translations.*)

CAMBRIDGE, MASS., April 16, 1902.

To Lick Observatory. (Received 11:00 A. M.)

BROOKS telegraphs that he has confirmed his discovery of a comet on April 14th; its position at 16^h (Eastern Standard Time), April 15th, was R. A. $23^h\ 8^m\ 10^s$; Decl. $+27°\ 25'$; its daily motion 12^m east and 2° south; brightish, with tail.

(Signed) E. C. PICKERING.

MT. HAMILTON, CAL., April 17, 1902.

To Harvard College Observatory. (Sent 9:30 A. M.)

To Students' Observatory, Berkeley.

Comet Brooks was observed by AITKEN on April 16.9946 G. M. T. in R. A. $23^h\ 21^m\ 7^s.7$; Decl. $+25°\ 12'\ 25''$.

(Signed) W. W. CAMPBELL.

CAMBRIDGE, MASS., April 17, 1902.

To Lick Observatory. (Received 1:00 P. M.)

Kiel cables that Comet Brooks was observed by POSTELMANN at Koenigsberg on April 16.5521 G. M. T. in R. A. $23^h\ 15^m\ 41^s.1$; Decl. $+26°\ 6'\ 35''$.

(Signed) E. C. PICKERING.

BOSTON, MASS., April 27, 1902.

To Lick Observatory. (Received 10:00 A. M., April 28.)

Elements and ephemeris* of Comet 1902 *a* have been cabled from Kiel as follows:—

$$\begin{aligned} T &= \text{May } 7{:}12, \text{ G. M. T.} \\ \omega &= 228°\ 23' \\ \Omega &= 52\ 15 \\ i &= 66\ 30 \\ \text{Natural } q &= 0.4512. \end{aligned}$$

(Signed) J. RITCHIE, JR.

To Dr. CAMPBELL, BERKELEY, CAL., May 2, 1902.
Lick Observatory. (Received 11:20 A. M.)

Elliptic elements† and ephemeris* of Comet 1902 *a* were computed by STEBBINS, CURTISS, WEYMOUTH, and LEUSCHNER as follows:—

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* The ephemeris at four-day intervals is here omitted.

† According to a later message, these elements are referred to the Equator—not the Ecliptic.

T = May 28.39, G. M. T.
ω = 274° 30′
Ω = 35 3
i = 71 50
Natural q = 0.5542
e = 0.3947
Period = 0.88 years.

This is a rough approximation. The orbit indicates probable identity of this comet with Comet 1748 II.

(Signed) A. O. LEUSCHNER.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in the work of this department. Communications to this end may be sent to Frank Schlesinger, International Latitude Observatory, Ukiah, California.

During 1901 there were discovered thirty-six minor planets, all by photography, and all but one by the astronomers at Heidelberg, Germany. The thirty-sixth, discovered at Arequipa, is an unusually interesting one, its orbit having a large inclination to the ecliptic and having the greatest eccentricity (0.38) of any known minor planet. When discovered the planet was within 29° of the south pole.

Dr. Bauschinger, Director of the Berlin Rechen-Institut, has published a table of statistics of the minor planets discovered up to the end of 1900, which completes the first century of our knowledge of them. The ascending nodes show a decided tendency to cluster in the neighborhood of the ascending node of *Jupiter's* orbit which is in satisfactory agreement with Newcomb's theoretical results. There seems to be a slight tendency for great inclinations and great eccentricities to go together; but there is no connection between eccentricity and mean distance. Of the inclinations 315 are under 10°, 133 are between 10° and 20°, 29 between 20° and 30°, and one (*Pallas*) over 30°.

Arranging the planets in the order of mean daily motions, the gaps near 900″ and 600″ (that is, three times and twice *Jupiter's* mean daily motion) are very strongly marked. There are other less strongly marked gaps. The minor planets may accordingly be divided into three groups:—

The *Mars* Group, with mean daily motions between 2,015″ and 900″
The *Chief* Group, " " " " 900″ " 600″
The *Jupiter* Group, " " " " 600″ " 400″

These groups number respectively 108, 337, and 18 planets.

Dr. Bauschinger expresses the opinion that very few minor planets brighter than the tenth magnitude remain to be discovered, but that the fainter ones show no signs of exhaustion.

A formula is given for determining the diameters of asteroids, the mean albedo (that is, the reflecting power per unit of surface) being assumed as 0.24, midway between those of *Mars* and *Mercury*. It goes without saying that no stress can be laid upon individual diameters deduced by this method, especially since we know from Professor BARNARD'S measures on the four brightest asteroids that their albedoes vary greatly. Following are the results of Professor BARNARD and Dr. BAUSCHINGER for these four planets:—

	Diameter in Miles.		Albedo.	
	BAUSCHINGER . .	. BARNARD.	BAUSCHINGER . .	. BARNARD.
Ceres	482	477	0.240	0.195
Pallas	364	304	0.240	0.257
Juno	182	120	0.240	0.488
Vesta	518	239	0.240	0.825

BAUSCHINGER'S diameter for *Eros* is 32 kilometers, or 20 miles. It would be 15 miles if the mean of BARNARD'S albedoes (0.44) were used.

The volumes of the twelve largest planets (Nos. 1, 2, 3, 4, 7, 9, 10, 15, 16, 22, 29, 349) form two thirds of the volume of all the known minor planets; and since the tiny planets now discovered add so little to the volume, Dr. BAUSCHINGER estimates that the entire family (including those to be discovered) would form a sphere of diameter 1,320 kilometers, or 830 miles. If the albedo 0.44 were used, this diameter would be reduced to 610 miles, or one thirteenth of the Earth's; the corresponding mass is one thirty-three-hundredths of the Earth's, or one fortieth of the Moon's.

Such estimates are apt to be fallacious; for there may be numerous planets of considerable relative mass near *Jupiter's* orbit which are faint, owing to their great distances from the Earth.

Only two new comets were observed in 1901. GIACOBINI'S comet, discovered on December 20, 1900, was but little observed, owing to its extreme faintness. It was observed by AITKEN on February 15th, with the 36-inch refractor, but this is an isolated position, as other measures ceased a month earlier. Dr. KREUTZ'S short-period ellipse represented the motion of the comet in February, but no further inquiry into the orbit has been made.

The brightest comet of the last twenty years was independently seen at several places in the southern hemisphere, being reported as early as April 12th, at Paysandu. The most northerly station at which it was observed is the Lick Observatory, but the orbit rests entirely on measures taken in the southern hemisphere. It moved through the constellations *Pisces, Eridanus,* and *Orion,* nearly parallel with the equator. Mr. MERFIELD, employing three normal places, extending from May 6th to June 6th, derived a very much elongated ellipse, but he appears to prefer a parabolic motion. This comet attracted considerable attention, as the nucleus on May 2d rivaled *Sirius* in luster, being decidedly elliptical in shape, while the tail had in it a dark rift, which gave it a bifurcated appearance.

The only other comet besides these two that has been under observation is that of ENCKE. The preparation of the ephemeris to assist its recovery was undertaken by Dr. THORNBERG of the Kronstadt Observatory, and the comet was found by Professor WILSON, of Northfield, Minn., on August 5th, very near the predicted place.

Two comets passed through perihelion without being seen, although looked for. J. D. G.

CHANDLER'S researches on the Variations of Latitude have led him to many collateral discoveries of the greatest interest. The most recent of these is his vindication of the *Reflex Zenith-Tube.* This instrument was designed and erected at Greenwich by AIRY, late Astronomer Royal for England. It is capable of measuring with great accuracy the zenith-distance of a star at its culmination, providing that this zenith-distance is not more than a few minutes of arc. If the star is bright enough to be observed during the daytime, and if the observations extend over several years, it is possible thus to determine the numerical values of aberration, nutation, and the star's absolute parallax. Such a series of observations was carried out by AIRY upon the star γ *Draconis,* but with most unsatisfactory results. The observations gave a large negative parallax for the star—manifestly impossible to be real—and a value for the aberration so small as to be out of the question. AIRY sought in vain to find the cause of these discrepancies in the instrument, and finally discontinued the observations with great disappointment in 1882. A few observations (about 300) were made with the instrument by the present administration of the observatory between 1886 and 1899, for the purpose of detecting if possible the cause of the anomalies, but again without satisfactory results. CHANDLER has just shown that when the variation of latitude (a phenomenon unthought of in AIRY's day) is taken into account, things become completely accounted for, and that the instrument has done a greater service for astronomy than even its builder thought it would do; for the observations made with it enable us to compute the variation of latitude during an early period (1857-1870). Since CHANDLER'S investigation has been published Mr. CHRISTIE, the present Astronomer Royal, has stated that the Reflex Zenith-Tube will again be put into service.

Professor W. H. PICKERING calls attention in the Monthly Notices of the Royal Astronomical Society to what he names the "green flash" at sunset. He has noticed several times that for a second or so, at the final disappearance of the Sun's upper limb below the horizon, a distinctly green color is seen. This he accounts for as a subjective phenomenon, or illusion, similar to the complementary color which one sees after gazing intently at a bright surface; as the edge of the Sun looks red at sunset, its withdrawal will leave upon the eye the impression of green. This explanation of PICKERING'S is, however, shown not to be the true one by several observers who have reported it at *sunrise,* just before the edge of the Sun makes its appearance. Lord KELVIN reported this phenomenon as seen at sunrise in the Alps three years ago, and Professor NIJLAND of Utrecht, Holland, has lately seen it several times at sea. No satisfactory explanation has yet been offered. Valuable observations of the "green flash" can be made by any amateur who has access to a site from which the Sun appears to rise or set in the true horizon. Observations may be made with the naked eye, though a small telescope or opera-glasses will be found advantageous. The observer should record failures to see the phenomenon and the general conditions of the sky, the temperature, etc., every time he looks for it.

The General Notes of the last number of these *Publications* contain a notice of KAPTEYN'S brilliant suggestion as to the nature of the nebulous light surrounding *Nova Persei.* This theory has received some confirmation since then, and, on the other hand, some contrary evidence has been adduced. The investigations of its parallax indicate on the whole that the

Nova is at the great distance demanded by KAPTEYN'S theory. Even more strongly in its favor is the fact pointed out by Mr. RITCHEY, that the appearance of new patches of nebulous light upon the photographs is just what we should expect if we are seeing different sections of dark matter successively lit up by the light of the *Nova*. If what we see were matter flying from the *Nova* with enormous velocities we should expect a certain degree of persistence of form. On the other hand, a telegram from the Lick Observatory announces that PERRINE could find no trace of polarization (the inevitable accompaniment of reflection) in the light of the nebula. For the present we may feel reasonably sure that we have to do with either such a condition as KAPTEYN supposes, or else, as WOLF suggested, with an electrical wave originating in the *Nova*. Still another theory has been advanced, similar to ARRHENIUS'S explanation of comet-tails,—namely, that the nebula is being driven from the *Nova* by light-pressure. It would appear that this last theory must be abandoned, as there would result from it an ever-increasing velocity in the expanding nebula; whereas uniform velocity is the observed fact.

Professor E. C. PICKERING announces the receipt of an unconditional gift of $20,000 to the Harvard Observatory by a friend whose name is not made public. Professor PICKERING states that he intends to expend half of it for the immediate erection of a proper building for storing astronomical photographs, and the other half as needs may arise. The reader is probably aware that Harvard Observatory, in conjunction with its station at Arequipa, takes photographs of the entire sky at frequent intervals. No attempt is made to examine the greater part of these; they are simply stored away for future reference. The great value of these photographs has been proven time and again. They have enabled astronomers to fix the time of the appearance of *Nova Aurigæ* in 1892 and of *Nova Persei* of last year. In a similar way our knowledge of *Eros*, discovered by WITT in 1898, was extended back several years. The first observations of many variables are also to be found on these plates. Professor PICKERING hopes to increase still further the usefulness of this ever-growing collection by making it accessible to all astronomers who care to consult it.

Professor **Porter**, Director of the Cincinnati Observatory, states that the observatory is to have a 16-inch equatorial telescope, to be made by the firm of **Alvan Clark & Sons**. A 30-foot dome to accommodate such a telescope was erected at the observatory some years ago. The telescope is to be devoted to researches in the "old" astronomy of precision.

During the recent troubles in China some of the German soldiery removed the quaint astronomical instruments from Pekin's famous observatory and sent them to Berlin. There was considerable feeling in Germany that the instruments should be restored to China, but this is not to be done, as the following extract shows. It is from a speech by the Imperial German Chancellor, before the Reichstag, reported in the *New York Sun* of April 27:—

> "The instruments have not been restored because the Chinese Government attaches no importance to their possession, and in reply to German inquiries, it placed them at the disposition of the German Government. Another consideration is, that in accordance with the peculiar views of the Chinese, the great mass of that people would have supposed that the instruments were restored by order of the Chinese Government, which would have damaged German prestige in East Asia. The Dowager Empress of China, a very clever woman who understands the political situation, would have been distinctly offended, while the masses would have thought that Germany had sustained some terrible defeats. The instruments ought now to be placed in the category of presents from government to government, as this has long been customary on both sides in our intercourse with China."

S. W. **Burnham**, whose leisure has been so fruitful of astronomical discoveries, has resigned his office as clerk of the U. S. District Court for the Northern District of Illinois, and intends hereafter to devote all his attention to astronomy.

Frank E. Ross (Ph. D., University of California, 1901) has been appointed Computer in the Nautical Almanac Office at the Naval Observatory, Washington, D. C.

J. N. **Krieger**, an astronomer who occupied himself solely in the study of the Moon's surface, died at San Remo, Italy, in February last, in the thirty-seventh year of his age. **Krieger's** observations were made at the Pia Observatory, at Triest, Austria. He had planned to publish a complete atlas of the Moon in eight volumes, only one of which, however, had appeared at the time of his death. The material for the other volumes is said to be nearly complete, and no doubt will be published eventually.

On February 24th, RICHARD SCHUMACHER, observer at the Royal Observatory at Kiel, Germany, died at the age of seventy-five years. He was the son of H. C. SCHUMACHER, founder of the *Astronomische Nachrichten*, and had been at various times connected with the observatories at Altona, Santiago (Chile), and Kiel.

ERRATUM.—In these *Publications*, No. 81, page 221, line 24, *for* 6th magnitude, *read* 8.6 magnitude.

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
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PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1902.

BY MALCOLM MCNEILL.

SEPTEMBER.

The Sun crosses the celestial equator and the autumnal equinox occurs September 23d, 4 P.M., Pacific time.

Mercury is not favorably situated for naked-eye observation, although it is an evening star and at a considerable distance from the Sun. It reaches greatest east elongation on September 24th, and this elongation (26°) is the greatest east elongation for the year, since it occurs only eleven days after the planet passes its aphelion. But the planet is 10° south of the Sun, and this causes a great shortening of the interval between the setting of the Sun and the planet. The interval is less than one hour throughout the month. On September 20th *Mercury* passes 13′ south of the first magnitude star α *Virginis.*

Venus is still a morning star, but is beginning to approach the Sun quite rapidly, and the interval between rising of the planet and of the Sun shortens from about two hours to about an hour and fifteen minutes. It moves about 35° eastward and southward through the constellation *Leo,* and on September 11th passes south of the first-magnitude star *Regulus,* α *Leonis,* at a distance about equal to the Moon's apparent diameter.

Mars rises about three hours before the Sun; so it can be very easily seen in the early morning, although it has not yet brightened up enough to be at all conspicuous. It moves 19° east and 4° south in the constellation *Cancer.* No bright stars are near it, but it passes between γ and δ *Cancri* on September 15th.

Jupiter is above the horizon until after midnight. It is moving westward, retrograding, about 2° during the month in the constellation *Capricorn.*

Saturn is also in fine position for evening observation. It is in the same constellation as *Jupiter,* and about 17° west of that planet. Its motion is retrograde until September 26th, but is quite small in amount.

Uranus is in the western sky in the evening, and sets at about 9 P.M. at the close of the month. The nearest noticeable star is the third-magnitude *θ Ophiuchi,* 2° east and 2° south of the planet. The planet approaches the star about half a degree during the month.

Neptune rises before midnight soon after September 1st. It is in the western part of the constellation *Gemini.*

OCTOBER.

There will be an eclipse of the Moon on the evening of October 16th. It will be total, and will be visible generally throughout the United States. The totality will last from 9^h 19^m to 10^h 48^m, Pacific time, and the partial phase will begin about an hour before totality and continue an hour after totality is ended.

There will also be a partial eclipse of the Sun, visible only in the Eastern Hemisphere, on October 31st. The maximum obscuration will be about seven tenths of the Sun's diameter.

Mercury is too near the Sun to be seen until the end of the month, and passes inferior conjunction, becoming a morning star, on October 19th. It may be possible during the last few days to see it in the morning twilight, but the conditions are not very good.

Venus, which has been the brightest of the planets in the morning sky for months, is now drawing very close to the Sun and by the end of October rises only about half an hour before sunrise. However, the planet is so much brighter than the others that it may be possible to follow it throughout nearly the entire month.

Mars rises about one minute earlier each day, so that by the end of the month it appears above the horizon at a little after 1 o'clock in the morning. It can not, however, be seen by the naked eye for an hour or more after it rises, since it is still not very bright. It is about one quarter nearer us than it was in May, and consequently about twice as bright. It moves about 17° east and 6° south through *Leo,* and on October 20th it passes about 1° north of the first-magnitude star *Regulus,* *a Leonis.*

Jupiter sets two hours earlier than during September, but is still in fine position for evening observation. Shortly after the beginning of the month it resumes its eastward motion, and by the end of the month it has about the same position among the stars that it held in early September.

Saturn sets about an hour before *Jupiter,* but is still in good position for early evening observation. It also moves eastward about 1° during the month.

Uranus sets quite early in the evening, and is too low down after twilight disappears for easy identification.

Neptune rises late in the evening. It is moving slowly westward in *Gemini.*

SEPTEMBER–OCTOBER, 1902.

PHASES OF THE MOON, P. S. T.

New Moon, . . .	Sept. 1,	9^h	19^m	P. M.
First Quarter, . . .	Sept. 9,	2	15	
Full Moon, . . .	Sept. 17,	10	23	A. M.
Last Quarter, . . .	Sept. 24,	8	31	
New Moon, . . .	Oct. 1,	9	9	
First Quarter, . . .	Oct. 9,	9	21	
Full Moon, . . .	Oct. 16,	10	1	P. M.
Last Quarter, . . .	Oct. 23,	2	58	
New Moon, . . .	Oct. 31,	12	14	A. M.

THE SUN.

1902.		R. A.	Declination.	Rises.	Transits.	Sets.
Sept.	1,	10^h 39^m	+ 8° 32′	5^h 31^m A. M.	Noon	6^h 29^m P. M.
	11,	11 15	+ 4 49	5 41	11^h 57^m A. M.	6 13
	21,	11 51	+ 0 58	5 50	11 53	5 56
Oct.	1,	12 27	— 2 55	6 0	11 50	5 40
	11,	13 4	— 6 46	6 10	11 47	5 24
	21,	13 41	— 10 28	6 21	11 45	5 9
	31,	14 19	— 13 54	6 32	11 44	4 56

MERCURY.

Sept.	1,	11 46	+ 1 54	7 0 A.M.	1 7 P.M.	7 14 P.M.
	11,	12 38	− 5 12	7 37	1 20	7 3
	21,	13 23	−11 15	8 4	1 25	6 46
Oct.	1,	13 56	−15 24	8 12	1 18	6 24
	11,	14 1	−15 44	7 39	12 44	5 49
	21,	13 26	− 9 45	6 3	11 30 A.M.	4 57
	31,	13 14	− 5 51	4 59	10 39	4 19

VENUS.

Sept.	1,	9 13	+16 53	3 35 A.M.	10 34 A.M.	5 33 P.M.
	11,	10 1	+13 15	3 57	10 43	5 29
	21,	10 49	+ 8 59	4 20	10 51	5 22
Oct.	1,	11 35	+ 4 18	4 44	10 58	5 12
	11,	12 21	− 0 38	5 5	11 4	5 3
	21,	13 7	− 5 35	5 30	11 11	4 52
	31,	13 53	−10 22	5 54	11 18	4 42

MARS.

Sept.	1,	8 1	+21 29	2 5 A.M.	9 22 A.M.	4 39 P.M.
	11,	8 28	+20 12	1 58	9 10	4 22
	21,	8 53	+18 42	1 50	8 56	4 2
Oct.	1,	9 18	+17 2	1 42	8 41	3 40
	11,	9 42	+15 15	1 33	8 26	3 19
	21,	10 5	+13 21	1 23	8 9	2 55
	31,	10 27	+11 24	1 13	7 52	2 31

JUPITER.

Sept.	1,	20 47	−18 52	5 13 P.M.	10 6 P.M.	2 59 A.M.
Oct.	1,	20 40	−19 18	3 10	8 2	12 54
Nov.	1,	20 45	−18 56	1 12	6 5	10 58 P.M.

SATURN.

Sept.	1,	19 34	−21 51	4 12 P.M.	8 53 P.M.	1 34 A.M.
Oct.	1,	19 32	−21 57	2 13	6 54	11 35 P.M.
Nov.	1,	19 36	−21 49	12 14	4 56	9 38

URANUS.

Sept.	1,	17 5	−22 56	1 48 P.M.	6 25 P.M.	11 2 P.M.
Oct.	1,	17 7	−22 59	11 52 A.M.	4 29	9 6
Nov.	1,	17 12	−23 5	9 55	2 32	7 9

NEPTUNE.

Sept.	1,	6 15	+ 22 18	12 15 A.M.	7 36 A.M.	2 57 P.M.
Oct.	1,	6 16	+ 22 17	10 19 P.M.	5 40	1 1
Nov.	1,	6 15	+ 22 16	8 16	3 37	10 58 A.M.

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

I, R,	Sept.	1,	2^h	40^m	A.M.	III, D,	Oct.	1,	5^h	25^m	P.M.
I, R,		2,	9	9	P.M.	III, R,		1,	8	58	
II, R,		5,	10	35		I, R,		2,	11	18	
I, R,		9.	11	4		I, R,		4,	5	47	
I, R,		11,	5	32		II. R,		7,	10	22	
II, R,		13,	1	12	A.M.	III, D,		8,	9	26	
IV, R,		15,	4	53	P.M.	III, R,		9,	12	59	A.M.
I, R,		17,	12	59	A.M.	I, R,		11,	7	42	P.M.
I, R,		18,	7	26	P.M.	I, R,		18,	9	38	
II, R,		23,	5	7		I, R,		20,	4	7	
III, R,		24,	4	57		II, R,		25,	4	56	
I, R,		25,	9	23		I, R,		25,	11	33	
I, R,		27,	3	52		I, R,		27,	6	2	
II, D,		30,	7	44							

DEFINITIVE DETERMINATION OF THE ORBIT OF COMET 1898 I.

[Abstract of No. 3 of the *Astronomische Abhandlungen*.]

BY HEBER D. CURTIS.

Comet 1898 I was discovered by Professor C. D. PERRINE at Mt. Hamilton on March 19, 1898. At this date it was about equal to a sixth-magnitude star, with a head nearly 2′ in diameter and a broad fan-shaped tail about a degree in length. In all, the comet was observed 666 times at thirty-four observatories. Deducting for incomplete observations, 640 were made in Right Ascension and 639 in Declination. The comet had just passed perihelion (March 17th) and was visible for nine months, during which time it swept over a heliocentric arc of 110°.

The comet presented no unusual phenomena in physical appearance or spectrum, with the exception of a sharp fan-shaped jet in the head, which was observed by Perrine on April 7th, and was still visible one month later. There was a very well-marked nucleus, which in good seeing was of star-like sharpness. Traces of this nucleus were still seen at Mt. Hamilton in the middle of September.

Telescopic comets of long apparition period and considerable range in distance from the Sun and from the Earth afford an excellent test for the applicability of the various laws which have been suggested in explanation of the decrease in the light of comets as they recede from the Sun. Estimates on such objects can be made in magnitudes much as stars are compared, and with much the same accuracy. As Comet 1898 I had a range of over ten magnitudes (6.5 to 16.7) during the nine months of its apparition period, in which time its radius-vector varied in length from 1.1 to 3.5 units, it may be of interest to compare its loss of light with the various formulæ which have been suggested. Eighty-eight estimates of the brightness of the comet as a whole were made at various observatories and sixty-seven of the starlike nucleus. The loss of light in the nebulosity as a whole and in the nucleus seems to have been synchronous, and to have obeyed the same law within the limits of observation, but neither comet nor nucleus follows the formulæ $J = \frac{C}{r^2}$ (Deichmuller, *A. N.*, 3123), $J = \frac{C}{\Delta^2}$ (Olbers, *B. J.* 1819), nor the commonly accepted one, $J = \frac{C}{r^2\Delta^2}$, the difference on November 15th for the last expression being nearly seven magnitudes. The attempt was made to ascertain whether the variation in brightness could be expressed in the form $J = \frac{C}{\phi(r)\Delta^2}$. The various formulæ were applied to this comet and to several other comets of long apparition period, but no simple function of the inverse of r and Δ was found which would harmonize all the data. In the last column of the following abridged table will be found the residuals, in magnitudes, in the sense observation minus computation, secured on the assumption that the light varied in accordance with the formula $J = \frac{C}{r^7\Delta^2}$. This formula is of course purely empirical and rests upon no physical basis; it is of interest simply in showing the inadequacy of the ordinary formula $J = \frac{C}{r^2 \Delta^2}$ for this comet.

a. Comet.

PLACE OF OBSERVATION.	DATE 1898.	OBSERVED MAG.	O–C $C/r^2\Delta^2$	O–C $C/r^7\Delta^2$
Mt. Hamilton..	March 20 0	6.0	−0.5	−0.5
Utrecht........	April 1.6	7.	+0 4	+0.4
Vienna........	May 1.5	7.4	+0.2	−0.5
Munich........	May 2.4	8.5	+1.3	+0 5
Munich........	June 4.4	10.3	+2.1	0.0
Mt. Hamilton..	June 19.9	10.	+1.4	−1 2
Munich..	July 16.5	12.0	+2.9	−0.6
Mt. Hamilton..	July 23.0	12.8	+3.6	−0.2
" "	Aug. 12.9	13.5	+4.0	−0.3
" "	Sept. 10.0.	16.	+6.2	+1.3
" "	Nov. 6.8	16.8	+6.8	+0.4
" "	Nov. 15.8	16.8	+6.7	+0.5

b. Nucleus.

PLACE OF OBSERVATION.	DATE 1898.	OBSERVED MAG.	O–C $C/r^2\Delta^2$	O–C $C/r^7\Delta^2$
Bamberg......	March 22.6	8.9	+0.9	+0.9
Mt. Hamilton..	March 30.0	8.0	0.0	−0.2
Utrecht........	April 13.5	9.0	+0.7	+0.4
Utrecht........	May 11.5	9.5	+0.4	+0 2
Mt. Hamilton..	June 6.0	11.5	+1.7	−0.6
" "	June 28.9	13.3	+2.9	0.0
" "	July 10.0	14.	+3.5	+0.3
" "	July 30.0	16.	+5.2	+1.3
" "	Aug. 14.9	16.5	+5.4	+1.1
" "	Sept. 18.0	17.?	+5.7	+0.6
" "	Oct. 14.9	16.5	+5.1	+0.3

The observations depend upon 354 comparison-stars, whose places were determined after a comparison of all available catalogue places. The parallax factors were recomputed with a value of 8″.80 for the Sun's parallax and the reductions to apparent place carefully checked.

The probable errors and weights to be assigned to each observer were found in part graphically, and from the weighted residuals nine normal places were formed. The comet did not pass near any of the planets, but the perturbations in rectangular coördinates were computed at intervals of sixteen days during the apparition period for all the planets except *Uranus* and *Neptune.*

The dates of the normal places, the residuals and the perturbations are given in the annexed table:—

EPOCH OF OSCULATION: MARCH 31.0.

No.	1898	$\Delta\alpha \cos \delta$	Pert. α	Weight	$\Delta\delta$	Pert. δ	Weight	OBSERVATIONS.	
								From	To
		″	″		″	″			
I	March 25.5	— 1.65	+ 0.002	132.5	— 1.20	— 0.001	153.0	March 19	March 31
II	April 14.0	— 0.72	+ 0.005	291.0	— 2.18	— 0.011	331.5	April 1	April 30
III	May 15.0	+ 1.22	+ 0.053	170.0	— 1.57	— 0.141	220.0	May 1	May 31
IV	June 16.0	+ 2.34	+ 0.387	51.0	— 1.90	— 0.259	83.0	June 1	June 30
V	July 18.5	+ 0.98	— 0.954	27.0	— 0.79	— 0.243	54.0	July 1	July 31
VI	Aug. 20.5	— 4.18	— 1.786	8.0	+ 1.58	— 0.147	16.0	Aug. 12	Aug. 28
VII	Sept. 16.5	— 7.26	— 2.725	10.0	— 0.14	— 0.100	20.0	Sept. 10	Sept. 19
VIII	Oct. 15.5	— 9.78	— 4.042	4.0	+ 2.35	— 0.332	8.0	Oct. 8	Oct. 19
IX	Nov. 11.5	— 6.30	— 5.330	7.0	+ 0.81	— 0.452	14.0	Nov. 6	Nov. 15

From these by the usual methods and with the application of the usual checks the following corrections to the elements were derived:—

$$
\begin{aligned}
d\,\mathrm{T} &= +\ 0^{\mathrm{d}}.011825 \pm 0^{\mathrm{d}}.001679 \\
d \log q &= +\ 0\ .0000524 \pm 0\ .0000093 \\
d\,\pi' &= +\ 1' \quad 8''.52 \pm 11''.03 \\
d\,\Omega' &= +\ 0 \quad 18\ .07 \pm 3\ .21 \\
d\,i' &= -\ 0 \quad 1\ .80 \pm 0\ .49 \\
d\,e &= +\ 0\ .0004639 \pm 0\ .0000706
\end{aligned}
$$

$$[vv] = 30''.64 \qquad [p\ vv] = 449''.1 \qquad [n\ n\ 6] = 450''.5$$

The sum of the squares of the weighted residuals has thus been reduced from 4213″ to 450″.

From these are derived the following definitive elements:—

EQUINOX OF 1898.0.

$$
\begin{aligned}
\mathrm{T} &= 1898 \text{ March } 17.13078 \text{ Gr. M. T.} \\
\omega &= 47^{\circ}\ 19'\ 11''.85 \\
\Omega &= 262\ \ 26\ \ 19\ .06 \\
i &= 72\ \ 31\ \ 47\ .01 \\
\log q &= 0.0395112 \\
e &= 0.9803852 \\
\text{Period} &= 417.2 \pm 2.2 \text{ years}
\end{aligned}
$$

In inclination and longitude of the node it somewhat resembles Comet Pons-Brooks, 1884, but here the resemblance ceases. Comets 1861 I and 1861 II, both well determined, have approximately the same period, but no other likeness except a high inclination, that of 1861 I being 85° 26′, and 1861 II, 79° 46′.

NOTICES FROM THE LICK OBSERVATORY.[*]

Prepared by Members of the Staff.

A List of Six Stars Whose Velocities in the Line of Sight are Variable.[†]

The following six spectroscopic binaries, discovered with the Mills spectrograph, are additional to the thirty-two binaries already announced:—

ϕ Persei ($\alpha = 1^{\mathrm{h}}\ 37^{\mathrm{m}};\ \delta = +50^{\circ}\ 11'$).

The variable velocity of this star was discovered from the second plate. The observations are:—

Date.	Velocity.	Measured by
1898, September 5	-2^{km}	Reese.
1900, December 16	$+24$	Reese.
"	$+23$	Campbell.
1901, October 15	-10	Reese.
November 11	-12	Reese.

This star has bright hydrogen lines, its bright $H\beta$ having been discovered by Espin (*Astr. Nach.*, No. 2963). The $H\gamma$ line may perhaps be best described as a comparatively narrow absorption line with very bright borders. The measures refer to the middle of the dark line. No other lines are apparent in the $H\gamma$ region.

η Geminorum ($\alpha = 6^{\mathrm{h}}\ 09^{\mathrm{m}};\ \delta = +22^{\circ}\ 32'$).

The observations of this star thus far secured are as follows, the variable velocity having been discovered from the third plate:—

Date.	Velocity.	Measured by
1900, January 15	$+15.8^{\mathrm{km}}$	Reese.
"	$+14$	Stebbins.
January 21	$+15.0$	Reese.

---

[*] Lick Astronomical Department of the University of California.

[†] From Lick Observatory Bulletin No. 20.

Date.		Velocity.	Measured by
1901, October	13	+22.1	REESE.
November	6	+20.3	REESE.
December	4	+22.8	REESE.
1902, February	2	+25	REESE.
"		+23	STEBBINS.

γ *Canis Minoris* ($\alpha = 7^h\ 23^m$; $\delta = +9°\ 08'$).

The observations of this star are:—

Date.		Velocity.	Measured by
1900, October	29	$+44^{km}$	REESE.
"		+44	STEBBINS.
1901, November	6	+41	REESE.
"		+40	STEBBINS.
December	22	+54	REESE.
"		+53	STEBBINS.
December	30	+50	REESE.

The fourth plate is underexposed.

ζ *Herculis* ($\alpha = 16^h\ 38^m$; $\delta = +31°\ 47'$).

Early observations of the radial velocity of this star were obtained by BELOPOLSKY at Pulkowa, CAMPBELL at Mount Hamilton, and NEWALL at Cambridge, as follows:—

Date.		Velocity.	Measured by
1893, May	18	-68^{km}	BELOPOLSKY.
May	22	−84	BELOPOLSKY.
June	2	−75	BELOPOLSKY.
June	3	−67	BELOPOLSKY.
June	4	−66	BELOPOLSKY.
June	14	−64	BELOPOLSKY.
June	16	−69	BELOPOLSKY.
Mean		−70.4	
1897, April	29	−69.1	CAMPBELL.
1898, May	11	−70.4	CAMPBELL.
May	23	−70.0	CAMPBELL.
August	19	−70.9	CAMPBELL.
Mean		−70.1	
1897, June	14	−71.4	NEWALL.
1898, May	16	−68.4	NEWALL.
1899, April	29	−74.3	NEWALL.
Mean		−71.4	

The above observations afforded no evidence whatever of variable velocity.

Recent observations at the Lick Observatory are as follows:—

Date.		Velocity.	Measured by
1901, July	1	-74^{km}	WRIGHT.
"		-73.9	REESE.
August	6	-75.8	REESE.
1902, April	13	-74.2	REESE.
Mean		-74.6	

The velocity has therefore changed about 4^{km} since 1898.

This star is a well-known visual binary, period about 33 years.

α *Equulei* ($\alpha = 21^h\ 11^m;\ \delta = +4°\ 50'$).

The variable velocity of this star was detected from the third of the following observations:—

Date.		Velocity.	Measured by
1900, June	25	-26^{km}	WRIGHT.
July	18	-22	WRIGHT.
1901, June	25	-2	WRIGHT.
September	1	-14	WRIGHT.
October	15	-12	REESE.
1902, June	2	-26	STEBBINS.

This star has a composite spectrum, discovered by Miss MAURY, of Harvard College Observatory.

o *Andromedæ* ($\alpha = 22^h\ 57^m;\ \delta = +41°\ 47'$).

The following observations of this star have been secured:—

Date.		Velocity.	Measured by
1900, October	9	-11^{km}	WRIGHT.
December	17	-15	CAMPBELL.
"	17	-17	WRIGHT.
1901, June	25	-20	WRIGHT.
August	12	-12	REESE.

These measures depend entirely upon the excellent $H\gamma$ line.

This star has a composite spectrum, discovered likewise by Miss MAURY.

Before the discovery of the thirty-eight spectroscopic binaries with the Mills spectrograph, three had been discovered in the same list of stars by BELOPOLSKY, making forty-one binaries in about 350 stars observed. The proportion is therefore one binary star for every eight observed, not taking into account a considerable list of suspected cases awaiting confirmation. The variable velocity of our Sun, due to its revolving planets, has a double amplitude of only a few hundredths of a kilometer. As the work progresses, and the degree of accuracy attainable increases, we shall probably find that there is a regular gradation of double amplitudes from that of the Sun up to those of the spectroscopic binaries already discovered, and it is possible that the star which is not a spectroscopic binary will prove to be the rare exception.

Acknowledgements are due to Messrs. WRIGHT and REESE for continued efficient assistance in the line of sight work.

July 1, 1902. W. W. CAMPBELL.

GIFT TO THE LICK ORSERVATORY.

Mr. D. O. MILLS has again shown his interest in astronomical work by providing the sum of one thousand dollars to defray the expenses of reconstructing the Mills spectrograph. Dr. REESE has designed the new mounting. It will be constructed as far as possible of steel, and will include improvements suggested by our six years' experience with the Mills spectrograph.

W. W. CAMPBELL.

January, 1902.

GIFT TO THE LICK OBSERVATORY.

The thoughtful generosity of Mrs. PHŒBE A. HEARST, Regent of the University of California, has increased the available resources of the Lick Observatory for the calendar year 1902 to the extent of twenty-five hundred dollars. This sum is to be devoted to equipment purposes, and the efficiency of several of our departments will be greatly increased thereby.

June 12, 1902. W. W. CAMPBELL.

ANNOUNCEMENT CONCERNING ASTRONOMICAL PHOTOGRAPHS.

There has been a great demand in the past two years from institutions, investigators and teachers for copies of the Lick Observatory photographs of astronomical subjects. The unusual pressure of observational duties and the smallness of the staff has prevented compliance with these legitimate demands.

This is to announce that the Observatory is now prepared to supply lantern slides, transparencies, prints, etc., of any negatives in its collection, at moderate expense. It is assumed that such copies would be used for purposes of study and investigation; but the right to publish any or all copies without special permission from the Director of the Lick Observatory would not attach to the sale.

The collection of photographs in our possession is so extensive that it is not practicable to supply a detailed list. It includes the following subjects: The Sun; The Moon; Total Solar Eclipses (of January, 1889; December, 1889; April, 1893; January, 1898; May, 1900; May, 1901); Milky Way; Comets; Meteors; Spectra of nebulæ, comets, new stars, bright-line stars, coronas, stars for radial velocities, etc.; Crossley reflector photographs of nebulæ, star clusters, asteroids, etc., and of the nebulosity surrounding *Nova Persei;* Buildings, instruments, and views at the Lick Observatory; Miscellaneous.

Orders and inquiries may be addressed to the Director.

July 1, 1902. W. W. CAMPBELL.

NOTE ON THE SPECTRUM OF *NOVA PERSEI.*

Spectrograms of *Nova Persei* were secured at intervals during the fall and winter, up to January 7th. The spectrum remained, without appreciable change, as described by us in *Bulletin* No. 8. In that publication attention was called to the presence of the fine dark *H* calcium absorption-line; and the opinion was ventured that perhaps the corresponding *K* line was "absent only by reason of the fact that there the calcium vapor has nothing to absorb." To test this point, Mr. WRIGHT made a long exposure, sufficient to record the continuous spectrum in the *H* and *K* region. The fine dark *K* line is present.

In this connection it would be exceedingly interesting to know whether the absorption-lines of calcium, sodium, and other elements would be detected in the spectra of well-known gaseous nebulæ,—the exposures being long enough to record the continuous portions of their spectra.

W. W. CAMPBELL.
July 1, 1902. W. H. WRIGHT.

D. O. MILLS EXPEDITION TO THE SOUTHERN HEMISPHERE.

The 37¼-inch Cassegrain reflecting-telescope mirror, to be used by the Mills Expedition in determining the radial velocities of the brighter stars south of —30° Declination, was completed by the John A. Brashear Company on June 20th. The 9¾-inch convex secondary mirror has likewise been completed. Both are en route to Mt. Hamilton. The telescope mounting, designed in general plan by the Director, and in detail by the builders, HARRON, RICKARD & McCONE, of San Francisco, has for several months been set up for trial in the rear of the Observatory buildings. A three-prism spectrograph, designed by the Director, optical parts by BRASHEAR, and mounting by our instrument-maker, has been completed and tested. A modern steel dome, 30 feet in diameter, has been constructed by the Warner & Swasey Company. It is hoped that the expedition may be able to sail early in August for Valparaiso, to occupy a station near Santiago, Chile.

July 1, 1902. W. W. CAMPBELL.

NOTE ON VARIABLE STARS.

Harvard College Observatory Circular No. 65, under date of May 6th, contains the announcement of an interesting new variable star of the *Algol* type:—

> "A striking illustration of the value of the library of glass photographs collected at this observatory during the past seventeen years has been shown within the last few days. Comet *a* 1902 was discovered by Dr. BROOKS on April 14th, and it was found that a photograph had been taken here on April 3d with the 8-inch Draper telescope, approximately in the direction from which the comet came. An examination of this plate was accordingly made by Mrs. FLEMING, superposing it upon another plate of the same region taken with the same instrument on March 7, 1900. No trace of the comet was found, and in fact the elements now indicate that it was a little beyond the region covered by the photograph. One star, however, in the constellation *Lacerta*, according to HEIS, but in *Cygnus* according to the *Uranometria Nova*, appeared faint on the early plate and bright on that taken later. A further examination showed that this object was the north-preceding component of $+43°.4101$. Its position for 1900 is R. A. = $21^h\ 55.2^m$, Dec. = $+43°52'$. The difference in Right Ascension of the two components is about $2^s.0$; the difference in Declination, $0'.3$. A further examination showed that the star was generally bright and constant in light, so that it must be a variable of the *Algol* type."

An examination showed that this star had been photographed 407 times. On 388 of the plates the star was of maximum brightness (8.9), but on the other 19 plates the magnitude was less than 8.9. From a discussion of this material, Professor PICKERING concludes that the period of the variable is 31.4 days, more than three times as long as that of any other known star of the *Algol* type. The star remains at maximum brightness for 28 days, and takes about three days to go through its minimum, decreasing from 8.9 to 11.6 magnitude.

This star was observed here photometrically with the 12-inch equatorial on the nights of June 29th, 30th, and July 1st. The actual minimum was not obtained, as it came in the daytime, but a curve through the observations shows that the minimum occurred at a time very close to that predicted by Professor PICKERING. The next minimum, July 31^{d} 19^{h} 26^{m} G. M. T., will be more favorable, and it is hoped to obtain observations of it.

I have also under observation a list of about twenty other new variable stars, and four variables of very faint minima are being followed with the 36-inch refractor.

S. D. TOWNLEY.

MEASUREMENT OF CLOSE DOUBLE STARS.

Dr. HERMANN STRUVE, Director of the Königsberg Observatory, has recently advanced a doctrine in reference to the measurement of close double stars which will hardly be acceptable to double-star observers, who have the use of telescopes of the largest sizes and good atmospheric conditions. He states it as his opinion that, even under the most favorable circumstances, when the distance between the components of a double star is less than 0″.40 approximate estimations only of the position-angle can be obtained, and when the distance is under 0″.50 that it has not been demonstrated that the distance is given more accurately by micrometer measurement than by mere estimation, and, further, he regards the results of the attempts which have been made to supply this demonstration as purely illusory.

Every one of experience will, I think, be ready to admit that when an observer has become accustomed to a given telescope and given eye-pieces in connection with it, he may acquire an accuracy in the estimation of small angular distances which is surprisingly near the truth. But before he can make such estimates he must acquire a knowledge of the scale of his instrument and the effect of the eye-pieces employed. Now this knowledge can only be obtained practically by measuring distances of the same order of magnitude as those to be estimated or by relying upon such measures already made by an observer of experience. In either case the estimates, to be reliable, must be based upon measured or measurable quantities.

The angular diameter of the central disk of the image of a star of the fifth or sixth magnitude as formed by the thirty-six-inch refractor of the Lick Observatory is not much more than 0".10; the theoretical value is 0".13. The disks for faint stars are somewhat smaller than for bright ones. The apparent thickness of the spider threads used as micrometer-wires in this instrument is very approximately 0".10. When the atmospheric conditions are favorable, giving good images of the stars, and when a sufficiently high power is used the micrometer-wire even when fully illuminated may be seen as a dark line crossing and almost concealing the central disk of the star which it bisects. The appearance of the wire as a dark line crossing the disk makes the bisection of the disk perfectly definite; it also makes perfectly definite the simultaneous bisection of two separated disks as in the measurement of position-angle by means of a single wire, or of the distance by the use of two.

A double star having components equal or nearly equal in brightness can be measured with this instrument under such atmospheric conditions as often prevail at Mt. Hamilton, whenever the distance between the components is greater than the thickness of a micrometer-wire. When the distance is somewhat less than this, an elongation of the image is still very apparent and an approximate determination of the position-angle and distance may be obtained by measurement and not by mere estimation. When the apparent distance becomes as small as 0".05, the images coalesce and appear almost or quite round, even with the highest powers that are used; viz., 2400 and 2600. For distances greater than 0".15 the images of the stars under good atmospheric conditions are clearly separated, and then measures can be made with certainty. For a distance of a third of a second the images are separated by a space of several times their own diameters, and there is then

no excuse here for estimating such a distance rather than measuring it.
W. J. HUSSEY.

DISCOVERY OF THE DOUBLE STAR *IOTA SERPENTIS.*

With the thirty-six-inch refractor on the night of July 17, 1902, I found this 4.5th-magnitude star to be a close double. The components are of sensibly the same brightness. My measures of position angle and distance are as follows:—

1902.542	71°.4	0″.20	
.545	72 .3	0 .21	
1902.54	71°.8	0″.20	2 n.

The position of *ι Serpentis* for the epoch 1900.0 is:—

R. A. $= 15^{h}\ 37^{m}\ 5^{s}.51$.
Decl. $= + 19° 59′ 32″.2$.

Its proper motion is small.

I have also found some other new double stars in this vicinity. The 7.5th-magnitude star 4′ north and 9^{m} preceding *ι Serpentis* is one of these. Its distance is about a third of a second, and the components are of the same magnitude.
W. J. HUSSEY.

CHANGES IN THE LICK OBSERVATORY STAFF.

Dr. HEBER D. CURTIS has been appointed Assistant in the Lick Observatory for three years, dating from the departure of the Mills Expedition to Chile, with principal duties in spectroscopy. Dr. CURTIS is a graduate of Michigan University, A. B., '92, and A. M., '93; was professor of mathematics and astronomy in the University of the Pacific, 1897-1900; was an eclipse observer in Georgia, 1900, and Sumatra, 1901; and has this year taken his Ph. D. degree at the University of Virginia.

Mr. C. A. G. WEYMOUTH, of the class of 1902, University of California, has been appointed Fellow in Astronomy at the Lick Observatory.
W. W. CAMPBELL.

HONORARY DEGREE FOR DIRECTOR CAMPBELL.

The University of Wisconsin conferred the honorary degree of Doctor of Laws upon Professor W. W. CAMPBELL, Director of the Lick Observatory, at the last annual commencement, June 19, 1902.

In sending the diploma, the Acting-President, Dr. E. A. BIRGE, writes: "I am very glad that it is possible for the University of Wisconsin to recognize in this way your distinguished work, both as scientist and as the administrative officer and head of the great observatory which is under your charge."

PUBLICATION COMMITTEE.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in the work of this department. Communications to this end may be sent to FRANK SCHLESINGER, International Latitude Observatory, Ukiah, California.

The Force of Gravity at the Surface of the Earth.—Among the most useful instruments which the astronomer has at his disposal must be counted the pendulum. Not only does it furnish him with an accurate timepiece in his observatory, but it has enabled him to learn much about the shape of the Earth and the distribution of the material forming the Earth's crust. So important are these applications of the pendulum that many expeditions for this purpose have been sent to remote regions, chiefly during the last twenty years. At the present time the intensity of gravity has been determined at about fifteen hundred places, widely scattered over the Earth's surface. Dr. HELMERT, head of the Central Bureau of the International Geodetic Association at Potsdam, has recently issued a complete report on pendulum observations. This report contains an interesting map showing the distribution of the fifteen hundred stations. By far the greater number of these are in Europe; the badly neglected continents are South America and Australia, the former containing only eleven stations, and the latter only five. Thanks to many pole-seeking expeditions, the Arctic regions have been well surveyed as regards pendulum experiments. The most northerly station is in latitude 85° 55′, occupied by NANSEN in 1895. On the other hand, the Antarctic regions are totally vacant, the most southerly stations being in latitudes 63° and 56°, respectively. In Europe, in the United States, and in India there are many inland stations, but elsewhere the observations have almost exclusively been confined to the seacoast.

Within the past few months a method has been developed for the determination of gravity which, although much less accurate than pendulum experiments, has a larger sphere of usefulness, in that it may be employed at sea. Pendulum observations are, of course, impossible on the ocean, owing to the inevitable rolling of vessels. In the new method observations are made with a barometer and an hypsometer, the latter being an instrument for the precise determination of the temperature at which water boils. As this varies with the pressure to which the water is subjected (being greater for high pressures), we may thus compute with considerable exactness the atmospheric pressure. Now, the barometer may be employed for the same purpose, but it will give precise results only if corrected for the intensity of gravity acting upon the mercury. It will therefore be seen that simultaneous observations with these two instruments, placed at the same height above sea-level, will enable us to compute the intensity of gravity at any place.

A series of such experiments was made last year by Dr. HECKER on the Atlantic Ocean. Six hypsometers and four mercurial barometers were employed, accordant results being obtained from all these instruments. The result of Dr. HECKER'S observations is to show that the intensity of gravity on the sea is *normal;* that is, it is equal to the intensity upon the land in the same latitude. At first sight this result might seem an improbable one, because of the small density of the sea (about forty per cent) compared with that of the land at the Earth's surface. As the ocean is usually two or three miles deep, it will be seen that there is much less *mass* immediately under a vessel than under a point on land, and consequently we should expect gravity at sea to be less than normal. But it has been known for many years (or at least been regarded as probable) that the crust of the Earth underlying the ocean is more dense than elsewhere. Thus pendulum experiments on small isolated islands indicate greater gravity than normal; this is really equivalent to the case on the open sea, with the addition of the excess of the mass of the island over that of the water it displaces. Again, accurate geodetic operations show that the plumb-line on the shores of the ocean is deflected toward the latter. Finally, Arctic explorers have occasionally been able to make pendulum observations on the solid ice covering the deep sea, and these observations show normal intensities. It is interesting to note that the greater density of the Earth's crust underlying the oceans was deduced almost wholly from theoretical considerations by Archdeacon PRATT, of Calcutta, about the middle of the last century. The importance of Dr. HECKER'S observations lies in the confirmation they afford of

PRATT's hypothesis, or, as it is sometimes called, the *isostatic* hypothesis.

Variations of Latitude.—Three important papers on this subject have recently appeared,—two by Dr. CHANDLER, and the third by Professor KIMURA, who has charge of the Japanese station of the International Latitude Service. Dr. CHANDLER's first paper is a "New Study of the Polar Motion for the Interval 1890–1901" (*Astronomical Journal,* No. 522), the former date corresponding to the first accurate observational data on the subject. The discussion is notably unbiased by the author's previous researches, and the results differ somewhat from those formerly published by him. According to the present paper the path of the pole is the resultant of three independent terms: (1) a circular motion, having a period of *fourteen* months; (2) an *annual* motion in a flat ellipse; and (3) a motion in an ellipse of slight eccentricity, and having a period of about *thirteen* months. The second of Dr. CHANDLER's papers to which we have referred above is "On the Possible Existence of Still Another Term of the Polar Motion." This was put into a separate paper, in order, as the author says, "to separate what was fairly demonstrated, as it seemed to me, from what was problematical." The new term has a period of *fifteen* months and is extremely minute, having a coefficient of 0″.025. It will be seen that the polar motion, as defined in these two papers, is by no means a simple one, especially since some of the elements of the separate motions appear to be subject to slow changes; notably the amplitude of the first term, that with a period of fourteen months.

The third paper adds to the complexity of this already complex subject. Professor KIMURA shows that there is a variation, having a semi-amplitude of only 0″.03, and an annual period, which affects all stations alike, no matter how much they may differ in longitude,—that is, the effect is the same as though the center of gravity of the Earth were movable along the axis of rotation. If the mass of the Earth were all concentrated at its center, a movement of only five feet would account for Professor KIMURA's variation. Whether this term is real is a question which needs further data to decide. The evidence deduced by KIMURA in favor of its existence is strong, but the effect is very small, and the data were of necessity derived from observations made only in the Northern Hemisphere. Furthermore, as the term has an *annual* period, the effect may be an instrumental one. It is a fact, perhaps not without significance, that the maxima of KIMURA'S variation occur in July and January, when the Northern Hemisphere is hottest and coldest, respectively.

These three papers not only indicate the still unsettled nature of our knowledge of the subject, but they attest to the accuracy of modern latitude observations, permitting of the discovery and discussion of terms having coefficients of only two or three hundredths of a second.

In the death of MARIE-ALFRED CORNU, which occurred near Orleans, France, in April last, almost every branch of physical science has suffered a direct loss. Although in his sixty-second year, CORNU was unusually active, physically and mentally, and his death was most unexpected. To astronomers he was best known through his determinations of the mean density of the Earth and of the velocity of light. Both these determinations exceeded in accuracy any work that had preceded them, and are still among the standard ones. Besides these, he has made many valuable contributions to astrophysics and some to astronomy of precision. One of the latest of these was his design for a "zenith-nadir" instrument, to be used in determining the constant of aberration and the variation of latitude.

TH. BREDIKHINE, the well-known astronomer at Moscow, Russia, has established a biennial prize of about two hundred dollars as a memorial to his late wife. The prize is to be "for the encouragement to the continuation of the work of TH. BREDIKHINE on the development of cometary forms, from a purely mechanical point of view."

The Secretary of the Smithsonian Institution has granted an annual award of two hundred dollars for a period of four years to the *Astrophysical Journal*. This is to be used in maintaining the high standard of excellence of the *Journal*, especially as regards illustrations.

The Catalogue of the Astronomische Gesellschaft.—Two new installments of this great work have been distributed, those for the zones 30°–35° and 35°–40°. Only one more zone, 70°–75°, remains to be published. The following table gives some of the details concerning the various parts of the catalogue:—

Zone.	Observatory.	Date when Published.	No. of Stars.
75° - 80°	Kasan	1898	4,281
70 - 75	Dorpat	. .	. .
65 - 70	Christiania	1890	3,949
55 - 65	Helsingfors and Gotha	1890	14,680
50 - 55	Harvard	1892	8,627
40 - 50	Bonn	1894	18,457
35 - 40	Lund	1902	11,446
30 - 35	Leiden	1902	10,239
24¼ - 31	Cambridge, Eng.	1897	14,464
20 - 25	Berlin	1895	9,208
15 - 20	Berlin	1896	10,161
10 - 15	Leipzig	1900	9,547
5 - 10	Leipzig	1899	12,785
1 - 5	Albany	1890	8,241
-2 - +1	Nicolajew	1900	5,954

The whole catalogue, extending from South Declination 2° to North Declination 80°, covers a little more than half the area of the sky, and when the Dorpat zone is published will contain observations of the highest order on more than 130,000 separate stars. A southern continuation of the catalogue is in progress, to be called "Part Two of the Catalogue of the Astronomische Gesellschaft." As regards the area between 80° North Declination and the pole, it will be remembered that this is so well covered by CARRINGTON'S "Catalogue of 3,735 Circumpolar Stars" (1857) that it was deemed unnecessary to include this part of the sky in the Gesellschaft programme.

Astronomischer Jahresbericht for 1901.—The third volume of this important publication does not differ in any material respect from its two predecessors. It contains reviews of 2,513 papers and books on astronomical and closely related subjects, as against 1,768 and 2,320 for the first and second volumes, respectively. The increase over the second volume is due to the appearance of *Nova Persei* in February, 1901, as no less than 228 reviews are devoted to this subject alone in the volume before us.

The work of reviewing so much material has, as heretofore, been done with truly astonishing completeness. How Dr. WISLICENUS can find time, in addition to his other duties, to read and epitomize an average of five papers or books a day is not easy to understand; and those who have had occasion to use the work will bear out the assertion that it shows no signs of having been hastily done. Almost all the reviews are written by Dr. WISLICENUS himself, the assistant editors serving chiefly to review works in the more uncommon languages. In this way it has been possible to include in the current volume reviews of papers in at least fourteen languages. It has been urged more than once against the *Jahresbericht* that too much space is devoted to reviewing popular articles. In this criticism we cannot concur; the work is thereby made more useful to amateurs, and it must be confessed that professional astronomers will profit by it as well,—for it is notorious that the latter, as a rule, do not spend much time upon technical papers outside of their own specialties. If they get a broad knowledge of their science at all, it is quite usually through the medium of popular exposition. In this connection we may recall the frank statement of the late Professor P. G. TAIT: "I have abstained from reading the details of any investigation (be its author who he may) which seemed to me to be unnecessarily complex. Such a course has inevitably certain disadvantages, but its manifest advantages far outweigh them."

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD AT THE LICK OBSERVATORY, JUNE 14, 1902, AT 9:15 P. M.

President PERRINE presided, and Dr. TOWNLEY was appointed temporary Secretary. A quorum was present. The minutes of the last meeting were approved as printed.

Mr. JOHN PATTON, of Baltimore, Md., was elected a life member of the Society.

A report of the Committee on Membership, appointed at the last annual meeting, was presented and read by the Secretary. Action on the report was deferred.

A communication from Professor M. MCNEILL, concerning the printing of planetary notes, was read and referred to the Publication Committee with power to act.

A communication from the chairman of the Publication Committee relating to the printing of the *Publications* was presented and read. After discussion, a motion was adopted directing the President of the Society to secure amendments to the present printing contract to insure greater promptness in publication.

The President announced gifts to the Society from Mr. WILLIAM ALVORD and from Mr. WM. M. PIERSON.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. C. D. Perrine	*President*
Mr. S. D. Townley	*First Vice-President*
Miss R. O'Halloran	*Second Vice-President*
Mr. Chas. S. Cushing	*Third Vice-President*
Mr. R. G. Aitken Mr. F. R. Ziel	*Secretaries*
Mr. F. R. Ziel	*Treasurer*

Board of Directors—Messrs. Aitken, Babcock, Campbell, Cushing, Leuschner, Molera, Miss O'Halloran, Messrs. Perrine, Pierson, Townley, Ziel.

Finance Committee—Messrs. Pierson, Cushing, Babcock.

Committee on Publication—Messrs. Aitken, Galloway, Schlesinger.

Library Committee—Mr. Townley, Miss O'Halloran, Mr. Brasch.

Committee on the Comet-Medal—Messrs. Campbell (*ex-officio*), Pierson, Burckhalter.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Felipe Valle.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

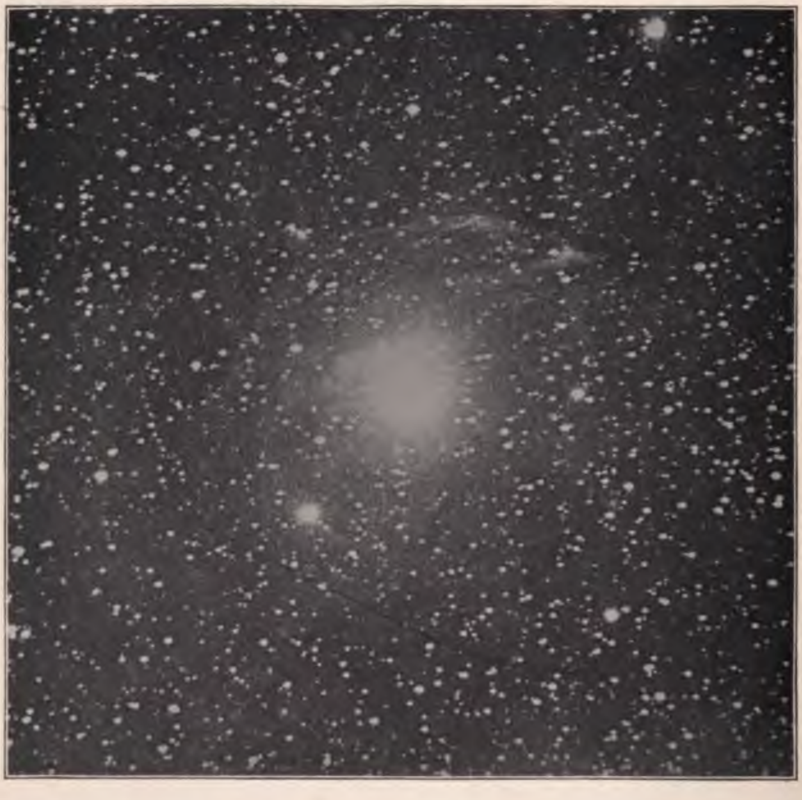
The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

THE NEBULOSITY AROUND NOVA PERSEI.

From a negative made with the Crossley Reflector of the Lick Observatory on March 29, 1901. Exposure 10 min.



From a negative made with the Crossley Reflector of the Lick Observatory on November 7 and 8, 1901. Exposure 7 h. 19 m.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XIV. SAN FRANCISCO, CALIFORNIA, OCTOBER 1, 1902. NO. 86.

PHOTOGRAPHS OF THE NEBULOSITY SURROUNDING *NOVA PERSEI*.

BY C. D. PERRINE.

The accompanying illustrations of the faint nebulosity around *Nova Persei* are direct photographic reproductions of negatives obtained with the Crossley reflector of the Lick Observatory. These plates have been enlarged to two and one-quarter diameters, and the contrasts very much strengthened by successive copyings of the original negatives. The scale of the illustrations is $1^{\mathrm{mm}} = 17''$. They have been selected from the series of eleven negatives which show this faint nebulosity. The principal movements and changes which have occurred are plainly visible.

The top of each plate is south.

The plate of March 29, 1901, shows the principal ring of nebulosity, which was visible on the photograph taken at that time. It is not quite continuous on the reproduction, but the brightest portions can easily be seen. A bubble in the glass of the original negative causes a defect in this ring on the west side. Some traces of the inner ring are to be seen, involved in the diffraction rings of the star. A faint, narrow arc of nebula can be made out in the northeast quadrant at a distance of 5′ from the *Nova*.

The photograph of November 12-13, 1901, shows the inner region of nebulosity much the best of any of the negatives. A great amount of structure is to be seen in all parts of this bright ring. The brightest condensations are to the south and southeast. It was the displacement of these masses which led to the detection of the rapid motion in this entire ring of nebulosity. The diameter of this bright ring is 15′.

Outside of this bright ring is another region of about 30′ diameter, which is filled with very faint nebulosity showing some structure. Two arcs of considerable length can be traced near the outer edge of this region to the south and southeast.

There are two defects in this plate due to scratches in the glass of the original negative.

The last illustration is from the photograph taken on the nights of January 31 and February 2, 1902. The inner ring has faded very much in the interval, and shows the bright mass of nebulosity nearest to the *Nova* to a better advantage. The principal features of this inner ring are still to be traced, but with less ease than on the photograph of November. The arrow-shaped mass, A, to the southeast is conspicuous. A comparison of the plates will show what great changes it has undergone both in position and structure in the interval of about twelve weeks. To the southwest and north, near the edges of the plate, are to be seen the wisps of nebulosity which have made their appearance since the photographs of November. These masses are found to be in motion, and have been increasing in brightness, while other portions of the nebula have been fading.

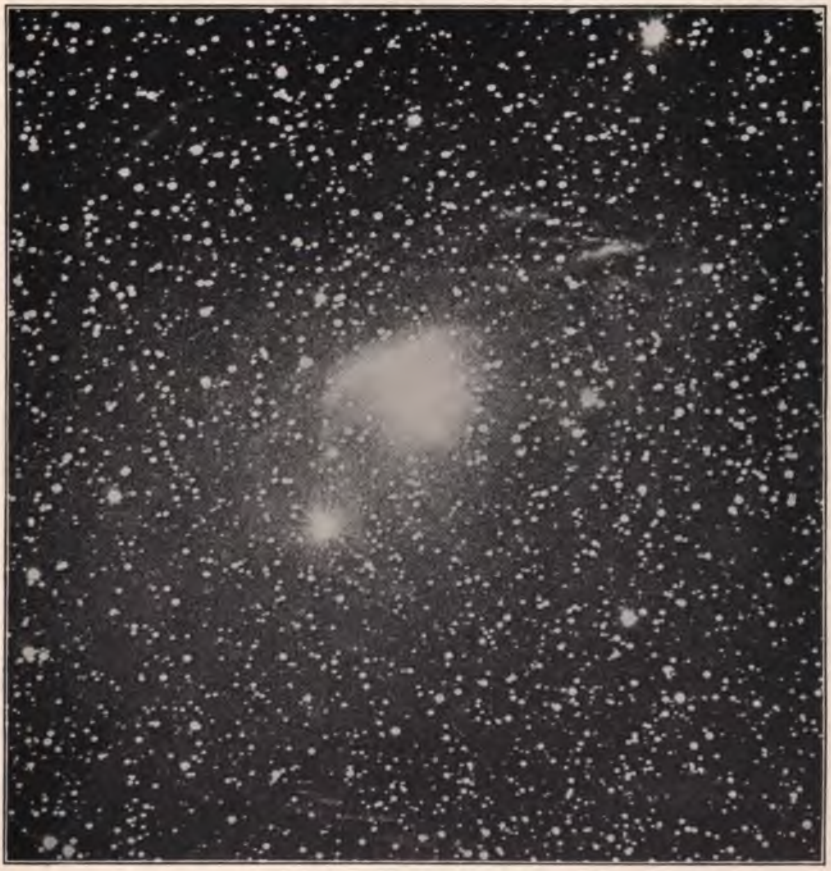
The phenomena observed in this nebulosity are very perplexing, and so far no theory seems to account satisfactorily for all the changes observed.

In March a negative was secured of the nebula with a double-image prism for the purpose of detecting any polarized light. The result is not entirely conclusive, but indicates that there is little or no polarization in the light of the only two masses which were bright enough to record themselves on the negative.

The negative of March 29, 1901, was taken by Messrs. H. K. Palmer and C. G. Dall. The others were obtained by the writer with the assistance of Messrs. H. K. Palmer and Joel Stebbins.

Mt. Hamilton, California, July 25, 1902.

THE NEBULOSITY AROUND NOVA PERSEI.



From a negative made with the Crossley Reflector of the Lick Observatory on January 31 and February 2, 1902. Exposure 9 h. 45 min.

THE ORBIT OF β *DELPHINI.*

By R. G. Aitken.

This investigation was undertaken to determine whether the observations of a close and difficult double star are sufficiently accurate to make it worth while to correct the elements of its approximate orbit by differential methods. Such methods have been applied in researches on the orbits of some of the moderately easy binary and ternary systems, as, for example, in Seeliger's classic memoirs on *Zeta Cancri.* But the orbits of the more difficult binaries have generally been based in part or wholly upon the graphic construction of the apparent ellipse, though the resulting elements have occasionally been improved by the use of Klinkerfues's very convenient method of six position-angles.

The system of *β Delphini* seemed well adapted for such an investigation. Though discovered by Burnham as recently as 1873, it has already completed a revolution. The maximum distance does not reach 0″.7, and its minimum distance, about 0″.2, does not fall below the resolving power of our larger telescopes. The pair has been, accordingly, well observed by all the leading double-star observers of the last quarter century, and a number of orbits have been computed. The two most recent ones, by See in 1895, and Burnham in 1898, are very similar in all their elements except the length of the semiaxis major.

The first step in the present investigation was to compare with these two orbits the observations of the star collected in Burnham's General Catalogue of his double stars. The comparison was made by drawing interpolating curves for the computed angles and distances derived from either orbit, and plotting the observed positions on the same scale. There seemed but little choice between the two curves for position-angles, See's representing the observed positions somewhat better at the two extremities, Burnham's those in the middle portion. But Burnham's distance-curve represents the distance-measures of the best observers far better than does See's.

Using See's elements as a basis, I next computed the following set of elements by KLINKERFUES's method of six position-angles:—

SYSTEM I.

$P = 27.94$ years
$T = 1883.230$
$e = 0.363$
$a = 0''.475$
$\Omega = 179^\circ.10$
$i = 61\ .75$
$\lambda = 352\ .80$

Interpolating curves were constructed from these elements, and the individual observations to 1902 compared with them, the measures having been taken from original sources. In this connection I wish to express my hearty thanks to Professor SCHIAPARELLI, who kindly sent me the full details of his fine series of measures of this pair.

Angle-measures that gave residuals exceeding 10° as the result of this comparison were rejected, unless the distance at the time of observation was as small as 0″.25. In this case the limit was set at 15°. Individual distance-measures were rejected only when they differed by 0″.2 from the computed, but an observer's mean result for any year was given weight zero if it differed by 0″.15 from the computed distances. The annual means were then formed by combining the measures of the various observers, assigning weights to each, depending in part upon the number of observations and in part upon the aperture of the telescope used.

When these annual means were compared* with the elements given above, it appeared that the distances were satisfactorily represented, but the residuals in angle seemed to show systematic deviations. The measures of each observer had already been examined for systematic errors of observation, but only two series of observations—SCHIAPARELLI's and BURNHAM's—were of sufficient extent to afford a basis for deriving reliable corrections for such errors, and their measures did not indicate appreciable errors of this kind.

A least-square solution therefore seemed unwarranted, and it was considered better to combine the annual means to form six normal position-angles and again apply KLINKERFUES'S method.

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* The details of this comparison and of the comparison of BURNHAM's and SCHIAPARELLI's observed positions with those derived from Elements II are given in Lick Observatory *Bulletin* No. 26.

These normal angles, with dates and residuals, are as follows:—

DATE.	Mean Anomaly. System I.	$\Delta\theta$ (o–c) System I.	Normal Angle.	Weight.	$\Delta\theta$ (o–c) System II.
1876.246	270°	— 1°.26	22°.64	22	— 1°.58
1882.066	345	+ 2 .45	159 .45	11	+ 1 .49
1885.946	35	— 0 .88	220 .94	15	— 4 .37
1888.662	70	+ 2 .56	300 .86	30	+ 1 .18
18 .318	130	— 0 .60	341 .27	70	— 0 .47
1899.526	210	+ 1 .40	364 .33	77	+ 0 .93

The elements resulting from this new solution are:—

SYSTEM II.

$P = 27.66$ years
$T = 1883.10$
$e = 0.363$
$a = 0''.475$
$\Omega = 178^\circ.90$
$i = 60\ .90$
$\lambda = 351\ .95$

The value of *a* was derived from several normal values of the observed distances based upon measures by BURNHAM, BARNARD, SCHIAPARELLI, COMSTOCK, HUSSEY, and AITKEN.

The last column in the table shows that these new elements represent all the normal places, except the first and third, better than System I. These two places—and the second as well—have much less weight than the last three; and it is to be remembered that they are based in large part upon measures with small telescopes. Considering this fact and the small apparent separation of the components of *β Delphini* in those years, we should expect larger errors in the measures made before 1887 than in the later ones.

I therefore regard System II as satisfactory, so far as the representation of the data at hand is concerned, and I think that the use of differential formulæ and a least-square solution will be of little service in improving these elements until more extended series of measures are available.

As the apparent orbital motion of this pair will increase rapidly during the next few years, I append an ephemeris, giving the relative positions of the two components according to Elements II for every tenth degree of mean anomaly to the date of the next periastron passage.

EPHEMERIS.

DATE.	M.	θ	ρ
1903.077	260°	18°.6	0″.48
1903.845	270	23 .6	0 .43
1904.613	280	30 .1	0 .37
1905.382	290	38 .9	0 .31
1906.150	300	51 .8	0 .26
1906.918	310	71 .2	0 .21
1907.687	320	97 .8	0 .19
1908.455	330	125 .7	0 .20
1909.223	340	147 .3	0 .24
1909.992	350	162 .8	0 .28
1910.760	360	175 .0	0 .30

September 7, 1902.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1902.

By MALCOLM McNEILL.

NOVEMBER.

Mercury is a morning star throughout the month, coming to greatest west elongation on the morning of November 4th. It will then rise about an hour and a half before sunrise, and until about November 20th it will be above the horizon at least an hour before the Sun. The present west elongation is only 19° (less by 8° than the east elongation of September), due to the fact that the planet passed its perihelion on October 24th, only a week before the time of greatest elongation.

Venus has been morning star since February 14th, but now comes to superior conjunction, and becomes an evening star on November 28th. It is almost too near the Sun to be seen at any time during the month.

Mars rises not long after midnight, coming to the horizon about one minute earlier each night. It moves 15° eastward and southward through *Leo* into *Virgo*. No very bright stars are near its path, but toward the close of the month it is somewhat to the west of *β Virginis*. It is beginning to approach the Earth quite rapidly, and consequently is beginning to be much brighter; but it is still faint as compared with its appearance when it is near opposition.

Jupiter is still in good position for early evening observation, but it sets shortly after nine o'clock at the close of the month. It is in quadrature with the Sun on November 1st, and during the month moves about 4° eastward and 1° northward in the constellation *Capricorn.*

Saturn is getting rather close to the Sun for good observation, although it does not set until about 8 P. M. at the close of the month. It is also in *Capricorn,* about 17° west of *Jupiter,* and moves more than 2° eastward during the month.

Uranus is still closer to the Sun than *Saturn* is, and in the same quarter of the heavens. It is entirely too low for such a faint object to be seen in the evening twilight. It moves about 2° eastward in the constellation *Ophiuchus.*

Neptune rises shortly after sunset. It is in the western part of *Gemini.*

DECEMBER.

The Sun reaches the winter solstice and winter begins December 22d, 10 A. M. Pacific time.

Mercury begins the month as morning star, too near the Sun to be seen, passes superior conjunction and becomes an evening star on December 12th, but hardly reaches a sufficient distance from the Sun to be visible to the naked eye until after the close of the month. It is in conjunction with *Venus* about midnight on December 21st, but both planets are then too near the Sun to be visible to the naked eye.

Venus becomes an evening star on November 28th, but it is rather slow about moving away from the Sun, reaching a distance of only about 8° at the end of the month. As it is also on the far side of its orbit beyond the Sun, it will be much less bright than usual, and it will hardly be possible to see it unless under exceptionally good conditions of the atmosphere.

Mars will rise before midnight at the close of the month. It moves eastward about 13° and southward about 5° in the constellation *Virgo,* and is beginning to slacken up its speed among the stars. It will begin to retrograde early in 1903. Its distance in millions of miles from the Earth diminishes from 145 to 118, and consequently it gains nearly one half in brightness during the month. So it has become a fairly conspicuous object.

Jupiter sets before 8 P. M. at the close of the month, and is therefore getting rather low for telescopic observation, but it is still fairly seen by the naked eye, and is in fact the most conspicuous object in that part of the evening sky. It moves 6° eastward during the month, but still remains in *Capricorn.*

Saturn is still lower than *Jupiter,* and at the close of the month sets less than an hour and a half after sunset. With its low altitude in the evening twilight, it is no longer a conspicuous object, but it is still far enough away from the Sun to be identified without aid from a telescope. It is also in *Capricorn,* and moves eastward more than 3° during the month.

Uranus comes to conjunction with the Sun on December 14th, changing from an evening to a morning star, but is too faint to be made out even with a telescope at such a short distance from the Sun as it has at any time during the month.

Neptune is in opposition with the Sun on December 24th, and is above the horizon practically the entire night.

NOVEMBER–DECEMBER, 1902.

PHASES OF THE MOON, P. S. T.

First Quarter, . . .	Nov. 8,	4ʰ	30ᵐ	A. M.
Full Moon, . . .	Nov. 15,	9	6	
Last Quarter, . . .	Nov. 21,	11	47	P. M.
New Moon, . . .	Nov. 29,	6	4	
First Quarter, . . .	Dec. 7,	10	26	
Full Moon, . . .	Dec. 14,	7	47	
Last Quarter, . . .	Dec. 21,	Noon.		
New Moon, . . .	Dec. 29,	1	25	P. M.

THE SUN.

1902.		R. A.	Declination.	Rises.	Transits.	Sets.
Nov.	1,	14ʰ 23ᵐ	— 14° 13′	6ʰ 33ᵐ A.M.	11ʰ 44ᵐ A.M.	4ʰ 55ᵐ P.M.
	11,	15 3	— 17 15	6 44	11 44	4 44
	21,	15 44	— 19 47	6 56	11 46	4 36
Dec.	1,	16 26	— 21 43	7 7	11 49	4 31
	11,	17 10	— 22 57	7 16	11 53	4 30
	21,	17 54	— 23 27	7 24	11 58	4 32
	31,	18 39	— 23 9	7 27	12 3 P.M.	4 39

Mercury.

Nov.	1,	13 17	− 5 57	4 57	A.M.	10 37	A.M.	4 17	P.M.
	11,	13 59	−10 0	5 14		10 40		4 6	
	21,	14 57	−15 44	5 54		10 59		4 4	
Dec.	1,	16 1	−20 41	6 37		11 23		4 9	
	11,	17 7	−24 1	7 18		11 50		4 22	
	21,	18 17	−25 17	7 53		12 20	P.M.	4 47	
	31,	19 27	−24 07	8 20		12 52		5 24	

Venus.

Nov.	1,	13 58	−10 49	5 56	A.M.	11 19	A.M.	4 42	P.M.
	11,	14 47	−15 9	6 20		11 28		4 36	
	21,	15 37	−18 50	6 46		11 39		4 32	
Dec.	1,	16 29	−21 39	7 8		11 51		4 34	
	11,	17 23	−23 25	7 31		12 6	P.M.	4 41	
	21,	18 18	−24 1	7 49		12 21		4 53	
	31,	19 13	−23 22	8 2		12 37		5 12	

Mars.

Nov.	1,	10 29	+11 12	1 11	A.M.	7 50	A.M.	2 29	P.M.
	11,	10 51	+ 9 13	1 0		7 32		2 4	
	21,	11 11	+ 7 15	12 48		7 13		1 38	
Dec.	1,	11 30	+ 5 20	12 35		6 53		1 11	
	11,	11 49	+ 3 31	12 20		6 32		12 44	
	21,	12 6	+ 1 48	12 4		6 10		12 16	
	31,	12 22	+ 0 16	11 45	P.M.	5 46		11 47	A.M.

Jupiter.

Nov.	1,	20 45	−18 56	1 12	P.M.	6 05	P.M.	10 58	P.M.
Dec.	1,	21 1	−17 51	11 26	A.M.	4 23		9 20	
Jan.	1,	21 25	−16 5	9 40		2 44		7 48	

Saturn.

Nov.	1,	19 36	−21 49	12 14	P.M.	4 56	P.M.	9 38	P.M.
Dec.	1,	19 46	−21 17	10 24	A.M.	3 8		7 52	
Jan.	1,	20 0	−20 52	8 35		1 20		6 5	

Uranus.

Nov.	1,	17 12	−23 5	9 55	A.M.	2 32	P.M.	7 9	P.M.
Dec.	1,	17 19	−23 13	8 6		12 42		5 18	
Jan.	1,	17 28	−23 21	6 12		10 47	A.M.	3 22	

Neptune.

Nov.	1,	6 15	+22 16	8 16	P.M.	3 37	A.M.	10 58	A.M.
Dec.	1,	6 13	+22 16	6 16		1 37		8 58	
Jan.	1,	6 9	+22 17	4 6		11 27	P.M.	6 48	

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

II,	D,	Nov. 1,	7^h	33^mP.M.	II,	R,	Dec. 3,	7^h	26^mP.M.
I,	R,	3,	7	57	I,	R,	5,	4	36
IV,	D,	4,	6	44	I,	R,	12,	6	31
IV,	R,	4,	11	28	III,	D,	19,	1	41
III,	R,	6,	5	5	III,	R,	19,	5	13
II,	R,	8,	10	12	I,	R,	19,	8	26
I,	R,	10,	9	53	II,	R,	21,	2	2
I,	R,	12,	4	21	I,	R,	21,	2	55
III,	D,	13,	5	34	III,	D,	26,	5	42
III,	R,	13,	9	6	III,	R,	26,	9	14
I,	R,	19,	6	17	II,	R,	28,	4	41
III,	D,	20,	9	35	I,	R,	28,	4	50
IV,	R,	21,	5	40					
II,	R,	26,	4	48					
I,	R,	28,	2	41					

THE SEARCH FOR AN INTRA-MERCURIAL PLANET AT THE TOTAL SOLAR ECLIPSE OF 1901, MAY 18.

By C. D. Perrine.

The considerable motion of the line of apsides of *Mercury's* orbit, found by LEVERRIER and others, cannot be explained by the attraction of the known bodies in the system, but would be fully accounted for by a planet or ring of planets between *Mercury* and the Sun.

The question is one which has attracted more or less attention from astronomers for over a century, and announcements have been made at various times of the supposed discoveries of such bodies. None of these announcements have ever been verified, however.

The solution of the problem is of peculiar difficulty. The necessary observations are possible only during the few minutes of a total eclipse, when the Sun's disk is entirely hidden. At any other time it would be impossible to detect an object very much fainter than *Mercury*.

The early searches at total eclipses were all made visually, and it was necessary to memorize the position and brightness of all the brighter stars in the region to be examined. The liability to mistake in the identification of stars was thus very great. Several of the supposed discoveries are probably due to this cause.

Searches by visual methods at a number of eclipses rendered it almost certain that there were no such bodies as bright as the third, and possibly the fourth, magnitude. But as to fainter objects there was no evidence whatever.

Since the introduction of the rapid dry-plate into astronomical work, it has become possible to attempt an adequate search for such bodies.

The first attempt, to my knowledge, to solve this problem with cameras of considerable focal length was during the eclipse of May 28, 1900. No definite results seem to have been obtained at that eclipse, however.

The great duration of totality (6½ minutes) in 1901 was very favorable for an intra-Mercurial planet search. The observations made in Sumatra for this purpose were described in the account of the Crocker Expedition from the Lick Observatory, published in No. 81 of the *Publications*. A re-examination of these plates has just been completed under more favorable conditions and has resulted in finding many fainter stars and some star-images on all of the plates.

Following is a summary of the results of the examination:—

No. of Plates.	STAR IMAGES.			REMARKS.
	Original Search.	Added by Re-examination.	Total Number.	
A_1 B_1	29	21	50	Faintest stars = one each of 9.1, 9.2, and 9.3 visual magnitude.
C_1 D_1	37	14	51	Faintest stars = two each of 8.6 and 9.0 visual magnitude.
A_2 B_2	26	9	35	Faintest stars = one each of 8.7 and 8.8 visual magnitude.
C_2 D_2	0	26	26	Faintest stars = three of 8.3, one each of 8.6 and 8.7 visual magnitude.
A_3 B_3	0	3	3	One star each of 6.0, 6.2, and 6.5 visual magnitude. *Mercury* and *Venus* are bright objects on the plates.
C_3 D_3	0	5	5	One star each of 4.0, 5.2, and 6.5 visual magnitude and two of 6.0 visual magnitude.
Total.	92	78	170	

Four out of the six regions covered by the photographs show stars from 8.7 to 9.3 visual magnitude. These were the first two sets of exposures. The clouds became thicker toward the end of totality, so that the set of exposures made then fails to show as faint stars. They, however, contain stars from 6.0 to 6.5 magnitude. Only two stars in the entire region, which were brighter than 6.0 visual magnitude, failed to record themselves on all of the plates. One of these was 5.0, the other 5.1 visual magnitude. According to the Draper Catalogue, the photographic magnitudes of these stars are 5.2 and 6.1, the former being a red star.

As the faintest stars recorded on the negatives are those which, in general, are more strongly actinic than a planetary body, it is necessary to make some allowance for this difference in deducing the limiting (visual) magnitude of the search. It seems probable that this difference would usually not exceed one magnitude. Hence if all the stars of 6.0 visual magnitude were recorded on the plates, a planet of 5.0 magnitude should be visible. The same criterion would indicate that in two thirds of the region searched, where stars of 8.7 to 9.3 magnitude were photographed, a planet as bright as 7¾ or 8.0 magnitude should have been recorded.

There is therefore little probability that any planet as bright as 5.0 magnitude exists in the region searched. While the clouds prevented the search from being definite to a much fainter magnitude, it is hardly possible that a ring of planets as bright as 8th magnitude can exist without some of them having been found.

From observations of the brightness of the four principal asteroids made at Harvard College Observatory and the measures of their diameters made by BARNARD at the Lick Observatory, it is found that such a body 300 miles in diameter appears on the average as a star of the 8.0 magnitude when seen from the Earth at opposition. If such a body were removed to the greatest probable distance from the Sun of an intra-Mercurial planet, it would appear to an observer on the Earth more than 110 times as bright, a difference of over five magnitudes. Hence we find that an intra-Mercurial planet to be of 5.0 magnitude would have to be only 75 miles in diameter, and one of 8.0 magnitude but 30 miles in diameter.

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The perturbations in the motion of *Mercury* would require a mass of matter about half as great as that of the planet itself. It would therefore take one million intra-Mercurial planets 30 miles in diameter, and as dense as *Mercury*, to cause the observed disturbances.

The observations made at this eclipse, although very much interfered with by the clouds, indicate that there are probably no bodies of appreciable size in the region close about the Sun, and that the cause of the disturbance in the motion of *Mercury* must be sought elsewhere.

The suggestion has also been made that these perturbations might be caused by a ring of bodies between *Mercury* and *Venus*. If this were true, it would seem that some effect should be observed in the motion of *Venus*.

Perhaps the finely divided matter composing the Zodiacal Light may be sufficient to cause these perturbations.

MT. HAMILTON, CALIFORNIA, August 27, 1902.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

THE OBSERVATORY INSTRUMENT-MAKING SHOPS.

A generation ago the astronomer ordered his telescope and expected it to meet all his requirements. This is no longer sufficient. The wonderful developments of our science call for special instruments to do special work, and the so-called universal instrument is out of date. The successful instrument must have the maximum efficiency in the problem to be solved. This is especially true in investigations along astrophysical lines. Every observatory of our class requires an instrument-making shop near at hand. This need is very pressing here, on account of our unusual isolation.

The shops at the Lick Observatory were entirely inadequate for their purpose. Up to one year ago, the equipment consisted of two small antiquated foot-power lathes, an antiquated hand-drill, files, etc., and the carpenter's hand-tools. The quantity of construction possible by their means was small, many vital parts of the instruments could not be made at all, vexatious delays in construction elsewhere were frequent, and our plans were rapidly falling in arrears to such an extent that the efficiency of the Observatory suffered severely. I therefore decided to devote the first available funds to the improvement of the machine-shops.

The carpenter-shop, paint-shop, and forge occupied adjoining rooms in a small brick building near the great dome, constructed by the Lick Trust. The paint-shop was removed to a distant isolated building, both to diminish risks from fire and to increase the space in the carpenter-shop. The inside walls of the forge-room were likewise removed. The resulting carpenter-shop is 20 × 26 feet inside. An addition to this shop was built by the Observatory workmen in 1891 (inside dimensions, 25 x 33 feet) from brick left in the orignal Lick Trust kilns. This room had been used for storage, for the metal-working shop, and for a steam boiler and engine employed in charging storage-batteries and in sawing the observatory wood. The engine and wood-saw were removed to a small brick building in 1901, to the east of the barn, and storage space has been found elsewhere. The rearranged room admirably meets the requirements of a complete instrument-making shop on the small scale desired. A Foos four-horse-power gasoline engine was installed in the shop in place of the steam engine. It drives the metal- and wood-working machines described below. It has the usual advantages of such an engine: it is always ready to start without waiting for steam to rise; the expense of fuel is small; it does not need the attention of a fireman; and it does not heat the work-room unduly.

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* Lick Astronomical Department of the University of California.

A Brown & Sharpe universal milling machine, a Brown & Sharpe tool-grinding machine, a modern wood-turning lathe, a wood rip-saw, and an emery grinder were purchased in 1901. The old foot-lathes were modified to adapt them to power, and it is planned to convert one of them into a grinding machine. The necessary shafting, pulleys, belting, attachments, and small tools were likewise provided. The gasoline engine also drives the dynamo.

The thoughtful generosity of Mrs. HEARST has enabled me to arrange for the completion of the shops without the delay that I feared must occur, by purchasing a modern lathe of fourteen-inch swing and eight-foot bed, with all necessary attachments; a power drill; a power saw for cutting metal; a cross-cut saw for wood; a wood-shaper; a small tempering and reducing furnace; and many minor tools.

It is planned to have all heavy work done elsewhere. For this reason, metal-shapers and other similar tools have been omitted from the equipment.

The press of work resulting from the remounting of the Crossley reflector, from the reconstruction of the Mills spectrograph, for which Mr. MILLS has provided funds, and from the construction of a modern one-prism spectrograph from the Draper Fund of the National Academy of Sciences, has made it necessary to employ temporarily a second instrument-maker, with salary paid from the two funds mentioned.

W. W. CAMPBELL.

A NEW RAPID BINARY STAR.

Recent measures of the double star A. 88 = Ll. 34524, which was discovered with the 36-inch telescope on June 2, 1900, have confirmed the fact suggested by the earlier measures that this pair is in rapid orbital motion. The mean results of measures for the three years are:—

1900.46	353°.2	0″.14	6.9–7.1	3^n	36-inch
1901.56	338 .3	0 .14		3	36-inch
1902.66	318 .1	0 .12		3	36-inch

The star's position for 1900.0 is:—

R.A. 18^h 33^m 9^s; Decl. — 3° 17′

September 9, 1902. R. G. AITKEN.

THE DISCOVERY OF 83 *AQUARII* AS A DOUBLE STAR.

In the course of my search for new double stars I examined the star 83 *Aquarii* with the 12-inch telescope on the night of July 29, 1902, and noted that it was apparently elongated. On August 16th an examination with the 36-inch telescope confirmed the fact of its duplicity. Measures have been obtained as follows:—

	θ	ρ	Seeing.	Eye-piece.	
1902.624	55°.8	0″.21	2+	1500	36-inch
.640	63 .8	0 .16	3	1500	36-inch
.643	62 .7	0 .20	3	1500	36-inch
.660	61 .5	0 .18	3	1500	36-inch
1902.64	61°.0	0″.19			

The two components are sensibly equal in brightness, each being estimated as of the sixth magnitude.

It is already evident that this pair of stars forms a physical system, for according to AUWERS it has an annual proper motion of 0″.023 in 17°.5. If this were not common to both components, the pair would have been an easy one in STRUVE's time, and would have been listed by him when he catalogued 83 and 84 *Aquarii* as the wide pair Σ 59^1.

The position of the star for 1900.0 is—

R.A. 22^h 59^m 57^s; Decl. — 8° 14′

September 9, 1902. R. G. AITKEN.

COMET *b* 1902 (PERRINE).

This comet was discovered in the morning of September 1st (civil time), in the constellation *Perseus.* The position of the comet at the time of discovery was—

$$\text{R.A. } 3^{h}\ 17^{m}\ 49^{s};\ \text{Decl. } +34^{\circ}\ 38'\ 47''$$

It was of about the 9th magnitude, with a nucleus of the 10½ or 11th magnitude. The head of the comet was 4′ or 5′ in diameter, and a very short tail extended toward the southwest.

Observations were secured on the morning of discovery and the two subsequent mornings, from which I have computed the following parabolic elements:—

$$T = 1902,\ \text{November } 23.4720\ \text{G. M. T.}$$

$$\left.\begin{array}{l} \omega = 153^{\circ}\ 25'\ 46'' \\ \Omega = \ \ 49\ \ \ 56\ \ \ 10 \\ i = 156\ \ \ 54\ \ \ 22 \end{array}\right\}\ 1902.0$$

$$\log q = 9.60424$$

Residuals, Obs.—Comp.

$$\begin{array}{ll} \Delta \lambda' \cos \beta' & +4'' \\ \Delta \beta' & -3 \end{array}$$

An ephemeris from these elements shows that the comet will be well placed in the northern sky during September and October, and that it will increase very much in brightness.

1902, September 4. C. D. PERRINE.

DISCOVERY OF TWO VARIABLE STARS IN THE NEBULA N. G. C. 7023.

This is one of the nebulæ on Professor KEELER's programme of work for the Crossley reflector. A comparison of two negatives, taken on November 7, 1901, and August 27, 1902, led to the discovery of two faint variable stars within the nebulosity. Their positions from the central star in the nebula are as follows:—

	p	*s*
A	6°.2	107″.1
B	138 .6	87 .4

Another photograph was taken on September 1st, and as a slight but certain change is noticeable in the interval of five days, the periods are probably comparatively short.

The following magnitudes have been assigned to the variables:—

	A	B
1901, November 7	14½	16¾
1902, August 27	16¼	15¾
September 1	16½	15½

So far as I am aware, no variable stars have heretofore been found in the nebulæ.

N. G. C. 7023 is an especially interesting nebula from its suggestive location in a region comparatively devoid of stars. The nebula is about 15′ across, and consists of irregular streamers and masses of nebulosity folded about a 7th-magnitude star.

Mr. JOEL STEBBINS and Mr. R. H. CURTISS, Fellows in Astronomy at the Lick Observatory, gave efficient assistance in the taking of the photographs. C. D. PERRINE.

MT. HAMILTON, CALIFORNIA, 1902, September 5.

ASTRONOMICAL TELEGRAMS.

(Translations.)

LICK OBSERVATORY, MT. HAMILTON, CAL.,
Sept. 1, 1902.

To Harvard College Observatory: (Sent 11:50 A. M.)

A comet was discovered by PERRINE on Sept. 1.0103 G. M. T.; in R. A. $3^h\ 17^m\ 49^s.4$; Decl. + 34° 38′ 47″. Its daily motion is — 10′ in R. A. and + 25′ in Decl. Its physical appearance is as follows: Slightly elongated, 4′ in diameter, 9th magnitude, with tolerably well-defined nucleus, and tail less than 30′.

(Signed) W. W. CAMPBELL.

LICK OBSERVATORY, MT. HAMILTON, CAL.,
Sept. 2, 1902.

To Harvard College Observatory: (Sent 10 A. M.)

Comet Perrine was observed by PERRINE on Sept. 1.9433 G. M. T.; in R. A. $3^h\ 17^m\ 3^s.0$; Decl. + 35° 0′ 34″.

(Signed) W. W. CAMPBELL.

LICK OBSERVATORY, MT. HAMILTON, CAL.,

To Harvard College Observatory: Sept, 3, 1902.

To Students' Observatory, Berkeley, Cal.: (Sent 10 A. M.)

Comet Perrine was observed by PERRINE on Sept. 2.8889 G. M. T.; in R. A. $3^h\ 16^m\ 9^s.6$; Decl. + 35° 23′ 35″.

(Signed) W. W. CAMPBELL.

LICK OBSERVATORY, MT. HAMILTON, CAL.,
Sept. 3, 1902.

To Harvard College Observatory: (Sent 9:00 P. M.)

Elements and ephemeris of Comet *b* were computed by PERRINE as follows:—

$$\begin{aligned} T &= 1902,\ \text{November } 24.47\ \text{G. M. T.} \\ \left.\begin{aligned} \omega &= 153^\circ\ 26' \\ \Omega &= \ \ 49\ \ \ 56 \\ i &= 156\ \ \ 54 \end{aligned}\right\} & \ 1902.0 \\ \text{Natural } q &= 0.4020 \end{aligned}$$

The brightness of the comet on Sept. 5 will be 1.5, on Sept. 18, 4.5.

(Signed) W. W. CAMPBELL.

[The ephemeris at 4-day intervals from Sept. 6 to Sept. 18 is here omitted.]

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in the work of this department. Communications to this end may be sent to Frank Schlesinger, International Latitude Observatory, Ukiah, California.

Early Knowledge of the Distances of the Stars.—The impression is quite general, but nevertheless erroneous, that astronomy had to wait until the nineteenth century for proper conceptions concerning the immensity of stellar distances. It is true that not until then were instruments perfect enough to enable actual measures of parallax to be made; but as early as the beginning of the eighteenth century the ***order*** of stellar distances was correctly inferred from methods not unlike and not inferior to those sometimes used at the present time for the same purpose.

In his recent book on "The Stars," NEWCOMB has the following paragraph (page 142):—

> "Considerations drawn from photometry were also lost sight of, because that art was still undeveloped. KEPLER saw that the Sun might well be of the nature of a star; in fact, that the stars were probably suns. Had he and his contemporaries known that the light of the Sun was more than ten thousand million times that of a bright star, they would have seen that if placed at one hundred thousand times its present distance the Sun would still shine as a bright star. If, then, the stars are as bright as the Sun, they must be one hundred thousand times as far away, and their annual parallax would then have been too small for detection with the instruments of the time. Such considerations as this would have removed the whole difficulty."

This method of estimating the distances of stars was originally proposed by JAMES GREGORY, who was born eight years after KEPLER'S death. HUYGENS (1629-1695) was the first to use it, and he concluded that *Sirius* (presumably one of the nearest of the stars) has a parallax of about 7″; a result which is too great, partly because *Sirius* is intrinsically brighter than the Sun, and partly because of the difficulty of estimating the relative brightness of such greatly different luminaries. This latter difficulty was overcome with great ingenuity by NEWTON (1642-1727), in whose *Principia* (page 547, MOTTE'S Translation) will be found these words:—

> "The disk of *Saturn*, which is only 17″ or 18″ in diameter, receives but about $\frac{1}{2,100,000,000}$ of the Sun's light; for so much less is that disk than the whole spherical surface of the orb* of *Saturn*. Now, if we suppose

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* That is, a sphere having a radius equal to the distance of *Saturn* from the Sun.

Saturn to reflect about one quarter of this light, the whole light reflected from its illuminated hemisphere will be about $\frac{1}{4,200,000,000}$ of the whole light emitted from the Sun's hemisphere; and, therefore, since light is rarefied in the duplicate ratio of the distance from the luminous body, if the Sun was $10,000\sqrt{42}$ times more distant than *Saturn*, it would yet appear as lucid as *Saturn* now does without its ring, that is, something more lucid than a fixed star of the first magnitude. Let us, therefore, suppose that the distance from which the Sun would shine as a fixed star exceeds that of *Saturn* by about 100,000 times, and its apparent diameter will be 0''.002, and its parallax arising from the annual motion of the Earth 0''.2; and so great will be the distance, the apparent diameter, and the parallax of the fixed stars of the first magnitude, in bulk and light equal to our Sun."

This estimate, made over two hundred years ago, can hardly be improved upon at the present day. It may be worth while to remark that modern measurements of the albedo of *Saturn* show that this planet reflects at least twice the fraction assumed by NEWTON.

Had this paragraph of NEWTON'S received more attention from his contemporaries and successors, it might perhaps have led to more hesitation in announcing large parallaxes and measurable diameters for certain stars. Even so late and so eminent an observer as the elder HERSCHEL thought he could detect the true disks of the brighter stars, and actually published some measures of their angular diameters.

The Tychonic System.—The above note suggests a word concerning TYCHO BRAHE'S system, in which the Sun and the Moon were supposed to revolve around the Earth, and the planets around the Sun. It seems to us that this system has been too severely dealt with by writers on Astronomy, who usually refer to it in such terms as "strange," "grotesque," and "unfortunate." It should be borne in mind that TYCHO'S system, so far as the Sun, Moon, and planets are concerned, is *geometrically* identical with that of COPERNICUS; that is, the relative motions of any two bodies are the same in either system. The greatest obstacle in the way of the general acceptance of the ideas of COPERNICUS was the lack of parallax in the stars. Men were just then striving to realize the great distance of the Sun from the Earth. Small wonder that they should hesitate to believe that this distance is a mere point in comparison with the distances to the stars. TYCHO'S system may therefore be said to fit in better with the observed facts than did that of

Copernicus. Especially will this appear to be true when we recall the state of mechanical knowledge at the time. The ideas concerning mechanics were then very vague, even as regards terrestrial phenomena; and the extension of these ideas to the heavens tended rather to disprove than to confirm the motion of the Earth. These considerations must increase our admiration for the genius of Copernicus, who was able to see beyond such formidable objections; but at the same time they should make us more lenient toward Tycho's system, which from the standpoint of a contemporary had much to commend it.

The Rate of a Clock in Constant Temperature and under Constant Pressure.—At the Case Observatory (Cleveland, Ohio) the experiment has been tried of subjecting an astronomical clock to constant pressure and temperature. The whole clock, together with a barometer and a thermometer, is inclosed in an air-tight compartment from which the air may be partly exhausted. By noting the reading of the barometer, and, if necessary, exhausting the air a little further, it is possible to keep the pressure sensibly constant. The whole arrangement is placed in a constant-temperature room. In this instance, the temperature is automatically kept unvaried by means of thermostats. Professor Howe has a paper in *Astronomical Journal* No. 524 on the performance of this clock. For a period of three months, in which the clock-error was observed sixteen times (rejecting three nights for reasons given), he finds the daily rates to vary at most only $0^s.022$ from the mean. The daily rates were computed by using the observations only in pairs; that is, each night with the following one. This method of computation is, if anything, unfavorable to the clock, as errors of observation have too large an effect on the rates. This is especially true in the present case because the intervals between observations are sometimes quite short —in one case only twenty-two hours. The writer of this note made a least-square solution to see how well the observed clock-errors would satisfy the assumption of a constant rate. He found that the largest residual (observed *minus* computed clock-corrections) was $0^s.3$. Another solution, using only the last two months, during which period the clock-correction had been determined thirteen times, gave no residual so great as $0^s.10$. Even this quantity, remarkably small though it is, cannot all be ascribed to irregularities of the clock; part of it is due to errors of observation and to errors in the almanac places of the stars, different sets having been used on different nights.

An interesting problem occuring in the method of least-squares is the following: What is the probable error of a given function of x, y, z, etc., when the values of the latter have been found from the same least-square solution? If x, y, z, etc., were independent of each other the answer would be quite simple, but it is clear that they are functions of the same observed quantities, and therefore functions of each other. The problem has been treated in its most general form by HELMERT in his *Ausgleichungsrechnung nach der Methode der kleinsten Quadrate* (page 139). In *Astronomical Journal* No. 523 Mr. HERBERT L. RICE gives a new demonstration of the fundamental formula and points out several places where eminent astronomers have been at fault on this point.

A List of New Variables.—The Committee on Variable Stars appointed by the *Astronomische Gesellschaft* has recently reported a list of twenty-four recently discovered variable stars, whose variability has been confirmed. Most of them were discovered by means of photography. Four of the variables are of the *Algol* type; that is, their light is constant, except for a short time at minimum. The list is rather unusual in the faintness of the stars even at maxima. Only one star reaches a magnitude between six and seven, the next brightest being between the eighth and ninth magnitude at its maximum. One star is never brighter than the eleventh magnitude. This would seem to indicate that most of the variables among the brighter stars have already been detected. It must be borne in mind, however, that in the present state of photometry a variable will probably escape detection unless it nearly doubles its light in going from minimum to maximum, or, in other words, unless it varies nearly three quarters of a magnitude or more. No doubt there are many stars which vary only one or two tenths of a magnitude, and quite possibly, when photometers are sufficiently improved, we shall find that a considerable fraction of all the stars are variable to some extent.

It is understood that the discoverer of a minor planet shall assign to it a feminine name. The only exception to this rule is the case of *Eros*, which, on account of its extraordinary orbit, is justly distinguished from others of the family. To find suitable names, with this restriction, for so many planets has overtaxed the ingenuity of the discoverers, until now no interest whatever attaches to the naming of a minor planet. Dr. DELISLE STEWART has, however, given a particularly apt name, *Occlo*, to the planet discovered by him at Arequipa, Peru, in 1901. *Occlo* was the first queen of the Incas, and, according to native mythology, she was the daughter of the Sun.

It is reported that $50,000 has been raised for an observatory at Amherst. The principal instrument is to be a refractor of eighteen inches aperture. The college already possesses a refractor with a 7¼-inch objective and a reflector of 12-inch aperture, and these will be suitably mounted in the new observatory. There are also to be two transit instruments, clocks, a spectroscope, etc. The observatory will be used for purposes of instruction as well as research.

The trustees of the Benjamin Apthorp Gould fund have granted $300 to Goodsell Observatory for the measurement of *Eros* parallax photographs.

Captain COLBY M. CHESTER, U. S. N., has been appointed Superintendent of the Naval Observatory, to succeed Captain C. H. DAVIS, who has been assigned to sea duty.

Dr. E. S. HOLDEN, formerly of the Lick Observatory, has been appointed Librarian at the West Point Military Academy. Dr. HOLDEN is an alumnus of this institution, of the class of 1870.

HERVÉ FAYE, the eminent French astronomer, died at Paris on July 4th. FAYE was born in 1814, and had been prominent in astronomy for sixty years. In 1843 he discovered the comet which bears his name, and which has a period of only seven and a half years. FAYE was connected with the famous Ecole Polytechnique, as student and professor, throughout nearly the whole of his life. He is most widely known through his theory of sun-spots and through his speculations on the origin of the universe. He was a member of the Academie des Sciences, of the Bureau des Longitudes, and of the International Geodetic Association.

In the death of ADELBERT SAFARIK, which occurred at Prague on July 2d, astronomy has lost another long-tried servant. SAFARIK was born in Hungary in 1829, and he received his training at Prague, Berlin, and Göttingen. His astronomical work consists in observations of the planets and the Moon, and especially of variable stars. In spite of the severe illness of the latter part of his life, he is said to have made during this period no less than twenty thousand observations of variable stars. SAFARIK had a broad knowledge of science in general; for a time he was professor of chemistry at Prague. But astronomy was always his favorite, and never were his observations entirely discontinued.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD AT THE LICK OBSERVATORY, ON SEPTEMBER 6, 1902, AT 9 P.M.

President PERRINE presided. A quorum was present. Two new members were elected to the Society, namely:—

THE LIBRARY OF THE U. S. MILITARY ACADEMY	West Point, N. Y.
Professor M. B. SNYDER	Director of the Philadelphia Observatory, Philadelphia, Pa.

The report of the Committee on Membership was then taken up. After full discussion it was moved, seconded, and carried that, in view of the financial questions involved (some mentioned in the Committee's report, and others brought out in discussion), the further consideration of the report be postponed until the regular business meeting in November; that the President be requested to call the meeting at such an hour as to secure a large attendance of the Board with suitable time for deliberation; that the President be requested to invite the attendance of Past-Presidents or others who may be especially interested; and that a copy of the Committee's report be sent in advance to each member of the Board and those specially invited.

The consenting votes of eight Directors having been secured, it was decided to make no award of the Bruce Medal for the year 1903.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT THE LICK OBSERVATORY, SEPTEMBER 6, 1902, AT 9:30 P.M.

President Perrine presided. The minutes of the last meeting were approved.

The following resolutions were presented, and on motion adopted:—

Whereas, Mr. William M. Pierson has generously offered to bear the deficit in the finances of the Society for the present fiscal year;

Resolved, That the thanks of the Society be tendered to him for this timely aid.

Whereas, Mr. William Alvord has generously contributed the sum of one hundred dollars towards the current expenses of the Society for the present fiscal year;

Resolved, That the thanks of the Society are hereby tendered to him for this opportune gift.

John Dolbeer, a member and former President of this Society, died at his home in San Francisco, on the 17th of August, 1902, at the age of 75 years, 4 months, and 25 days. He was born in Epsom, New Hampshire, in 1827, and came to California fifty-one years ago. During a long and active career in California he was engaged in many enterprises upon a large scale, chiefly appertaining to the lumber industry, and may well be regarded as among the builders of the West. Notwithstanding his active business life, he found time to assist in charitable and scientific undertakings, taking a deep interest, as an amateur, in astronomy.

He was a member of this Society, and had served as one of its directors and also as its President. In the year 1900 he fitted out at his own expense an expedition to observe the eclipse of the Sun at Siloam, Georgia, from which valuable scientific results were obtained. He made generous contributions to astronomical science, and, by his will, a large gift to this Society.

A Committee appointed by President Perrine, consisting of Messrs. Pierson, Molera, and Cushing, presented the following resolutions, which on motion were duly adopted as the expression of the sentiments of this Society:—

Resolved, That by the death of John Dolbeer this community has suffered the loss of a pioneer merchant, in whose career we recognize both the successful business man and the patron of art and science; that this Society has by his death, whether we consider him in the capacity of member, Director, President, or patron, lost one whose sturdy and intelligent support contributed largely to its success.

Resolved, That these resolutions be spread in full on our minutes, and that a copy thereof be sent to the relatives of the deceased as a slight token of our appreciation of our departed friend.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. C. D. Perrine	*President*
Mr. S. D. Townley	*First Vice-President*
Miss R. O'Halloran	*Second Vice-President*
Mr. Chas. S. Cushing	*Third Vice-President*
Mr. R. G. Aitken Mr. F. R. Ziel	*Secretaries*
Mr. F. R. Ziel	*Treasurer*

Board of Directors—Messrs. Aitken, Babcock, Campbell, Cushing, Leuschner, Molera, Miss O'Halloran, Messrs. Perrine, Pierson, Townley, Ziel.

Finance Committee—Messrs. Pierson, Cushing, Babcock.

Committee on Publication—Messrs. Aitken, Galloway, Schlesinger.

Library Committee—Mr. Townley, Miss O'Halloran, Mr. Brasch.

Committee on the Comet-Medal—Messrs. Campbell (*ex-officio*), Pierson, Burckhalter.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Felipe Valle.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
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THE LONGITUDINAL ABERRATION OF A PARABOLIC MIRROR.

By W. J. HUSSEY.

In the August-September number of *Popular Astronomy*, Professor WADSWORTH has given an investigation of the longitudinal aberration of a parabolic mirror. He calls attention to the difference between the formula for computing this quantity as given by Dr. DRAPER, viz.,

$$a = \frac{y^2}{4f}, \tag{1}$$

and that given by Mr. WASSELL and others, viz.,

$$a = \frac{y^2}{2f} + \frac{y^4}{16f^3}, \tag{2}$$

where a is the longitudinal aberration measured along the axis from the center of curvature for a zone of radius y of a parabolic mirror whose principal focal length is f.

Professor WADSWORTH concludes that the first of these expressions is correct and that the second is wrong. As a matter of fact, when properly interpreted, both formulas are rigorously correct. They are applicable to parabolic mirrors of any aperture and any focal length. They differ because they correspond to different methods of testing. The first formula assumes that the point-source of light and its image as formed by the zone that is being tested are made to coincide; that is, in testing a mirror having the aberrations computed by this formula the source of light and the eye-piece must move together along the axis of the mirror in passing from zone to zone. The second formula assumes that the point-source of light remains fixed at the center of curvature and that its images corresponding to the various zones do not coincide with it, except in the case of the central zone. In testing a mirror having the aberrations computed by the second formula the eye-piece alone is moved along the axis of the mirror in passing from zone to zone.

The above formulas may be derived easily, without recourse to calculus. Let Figure 1 represent a section of a paraboloid of revolution by a plane containing the axis. Let V be the vertex and F the focus of the parabolic section, and D the center of curvature of the parabola at the vertex. Then $VF = FD = f$. Taking the origin at the vertex and the axis of the parabola as the axis of abscissas, the equation of the parabola is

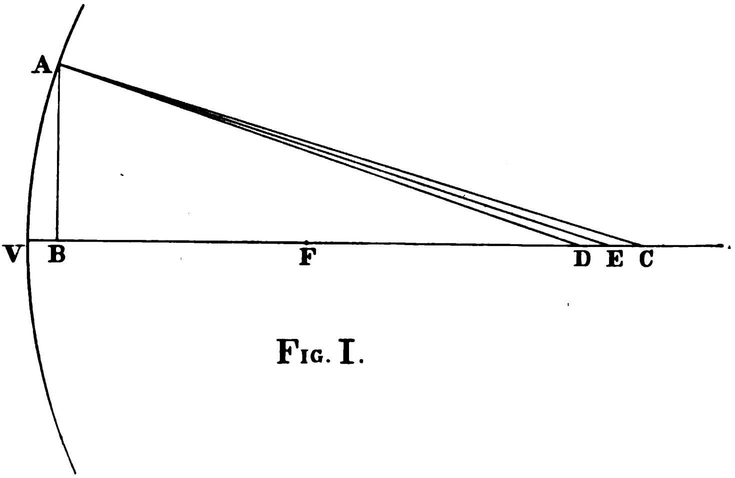

FIG. I.

$$y^2 = 4fx \tag{3}$$

Let A be a point in the parabola at a distance BA from the axis, and AE the normal to the parabola at A. Let the coördinates of A be x' and y'.

CASE I. *Point-source of light and its image coincident.*—Let the point-source of light and its image be placed at E. A ray EA meets the surface of the mirror normally at A and is reflected along the path AE. Moreover, all rays which emanate from E and make an angle equal to VEA with the axis are also reflected in paths which pass through E. E is therefore the image of E as formed by these rays, and the distance DE is the longitudinal aberration of the infinitely narrow zone A of radius $AB = y'$. The subnormal BE of the parabola is constant and equal to $2f$. VD is also equal to $2f$. Consequently, $DE = VB = x' = \frac{y'^2}{4f}$. Or, dropping the accents and writing a in place of DE, we have the required formula as follows:—

$$a = \frac{y^2}{4f}. \tag{1}$$

CASE II. *Point-source of light fixed at the center of curvature.*—Let the point-source of light be placed at the center of curvature D. A ray DA meets the surface of the mirror at A and is reflected along the path AC, making the angles DAE and EAC equal, these being respectively the angles of incidence and reflection. All rays which emanate from D and make an angle equal to VDA with the axis lie in the surface of a right cone which intersects the paraboloid in a circle of radius $AB = y'$, and they are reflected in rays which all lie in the surface of another right cone whose vertex is at C and whose semi-vertical angle is VCA. C is therefore the image of D formed by the rays which lie in the surfaces of the cones mentioned, and DC is the longitudinal aberration of the infinitely narrow zone A of radius $AB = y'$.

The coordinates of D are $2f$ and 0; those of E are $2f + x'$ and 0; and those of C are $2f + a$ and 0. Having the coordinates of A, D, E, and C, we may write the equations of the lines AD, AE, and AC. They are respectively as follows:—

$$y = \frac{y'}{x' - 2f}x - \frac{x'y'}{x' - 2f} + y', \tag{4}$$

$$y = -\frac{y'}{2f}x + \frac{x'y'}{2f} + y'. \tag{5}$$

$$y = \frac{y'}{x' - 2f - a}x - \frac{x'y'}{x' - 2f - a} + y'. \tag{6}$$

In these equations the coefficients of x are the tangents of the angles which these lines make with the axis of abscissas. Now, if m and m' are the tangents of the angles which any two lines make with the axis of abscissas, the angle θ included between these lines is given by the expression,

$$\tan\theta = \frac{m - m'}{1 + m\,m'}. \tag{7}$$

If we substitute in this the values of m and m' from the equations of *DA* and *AE*, and also those of *AE* and *CA*, we shall obtain respectively the tangents of the angles *DAE* and *EAC*. These angles are necessarily equal. We may therefore equate the values of their tangents. Doing this and solving the resulting expression for a, we obtain the following rigorous expression for the longitudinal aberration of a parabolic mirror:—

$$a = 2\,x' + \frac{x'^2}{f}, \tag{8}$$

or, substituting $\frac{y'^2}{4f}$ for x' and dropping the accents,

$$a = \frac{y^2}{2f} + \frac{y^4}{16f^3}. \tag{2}$$

A more general formula for the longitudinal aberration, of which the equation just given is a special case, may be readily derived. It is here considered as

CASE III. *Point-source of light situated upon the axis at a distance d from the vertex.*—The coordinates of the source of light are now d and 0. Let those of its image corresponding to the zone of radius y' be denoted by $h + a$ and 0, where h is the distance from the vertex at which the image is formed by that portion of the mirror which is situated at the vertex, and where a is the aberration required. In this case the aberration is reckoned from a point in the axis at a distance h from the vertex.

The argument and method here are the same as in the preceding case. The equations of the incident ray, the normal, and the reflected ray are respectively as follows:—

$$y = \frac{y'}{x' - d}\,x - \frac{x'\,y'}{x' - d} + y', \tag{9}$$

$$y = -\frac{y'}{2f}\,x + \frac{x'\,y'}{2f} + y', \tag{10}$$

$$y = \frac{y'}{x' - h - a}\,x - \frac{x'\,y'}{x' - h - a} + y'. \tag{11}$$

The expressions for the tangents of the angles included between the first and second, and between the second and third of these lines are formed and equated. When the resulting expression is simplified and x' eliminated through the use of the equation $y'^2 = 4fx'$, and the accents dropped, it reduces to

$$a = \frac{y^2}{2(d-f)} + \frac{y^4}{16f^2(d-f)} + \frac{f(d+h)-dh}{d-f}\,. \tag{12}$$

Now, from the manner of selecting the distance h, it will be seen that a and y vanish simultaneously. Consequently the constant term of the last equation is equal to zero. From this condition we get the relation between h and d, as follows:—

$$h = \frac{fd}{d-f} = f + \frac{f^2}{d-f}. \tag{13}$$

At the same time the preceding equation reduces to

$$a = \frac{y^2}{2(d-f)} + \frac{y^4}{16f^2(d-f)}, \tag{14}$$

which is the complete formula for the longitudinal aberration of an infinitely narrow zone of a parabolic mirror, the source of light being situated anywhere upon the axis.

If the source of light is placed at the center of curvature, $d = 2f$, and $h = 2f$, and the last equation reduces to

$$a = \frac{y^2}{2f} + \frac{y^4}{16f^3}, \tag{2}$$

as given in Case II.

If the source of light is placed at an infinite distance,—that is, if the mirror is directed to a star,—d becomes infinite and at the same time $h = f$, and $a = 0$. Or, in other words, rays parallel to the axis are brought to a focus from all parts of the mirror, free from aberration, at the principal focus of the mirror.

In the preceding paragraphs it has been assumed that the rays of light are reflected from an infinitely narrow zone of the mirror, the zone being circular and having its center in the axis of the paraboloid. The zones actually used in testing a mirror necessarily have a finite width. In consequence of this the rays of light which are reflected from the surface of such a zone as is used in practice do not all intersect in the same point of the axis. This will be evident from the following concrete example, which we shall regard as

Case IV. ***Point-source of light fixed at the center of curvature D and zone of finite width,*** **as indicated by *AB, A'B'* of Figure 2.**

According to these hypotheses the rays of light which are reflected from *A* and *B* respectively intersect the axis in points *C* and *G*, the aberrations *DC* and *DG* being those given by equation (2). Rays reflected from points between *A* and *B* meet the axis in points between C and G. The extreme rays AC and BG intersect in H, but since no other rays from the zone under consideration intersect in H, H is not an image of D as formed by rays from any portion of this zone. On the contrary, the rays which are reflected from that part of the surface from A to B inclusive, when taken in all possible combinations of two at a time, have points of intersection which completely fill the region HCG. The symmetrical portion of the zone $A'B'$ likewise furnishes rays which intersect the axis in points between C and G, and which when taken two at a time have points of intersection which completely fill the region KCG, symmetrical with HCG.

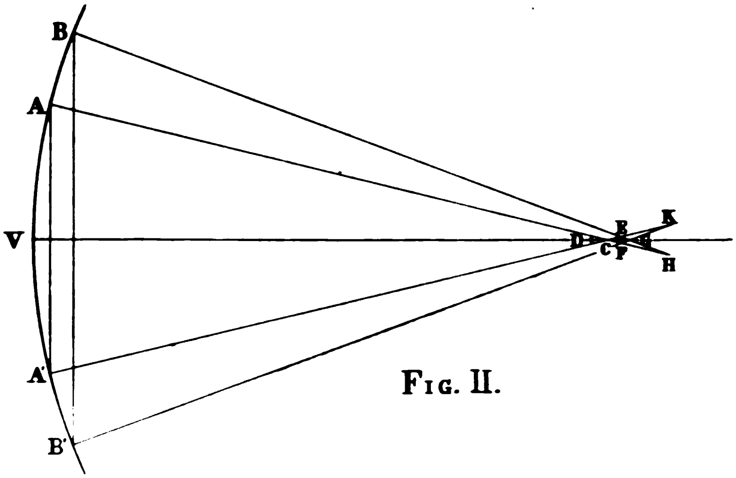

Fig. II.

The rays from A' and B, and those from A and B' intersect respectively in the points E and F. Let the line joining E and F

intersect the axis in *L*.* Then it is evident that *VL* is the distance from the vertex at which the cross-section of the rays reflected from the entire circular zone *AB*, *A'B'* has its minimum diameter. When the zone is of finite width, as here assumed, there is no point in which all the rays reflected from the zone intersect, and therefore there is no single all-embracing focal point. But in passing the circle of which *EF* is the diameter the rays are crowded together more closely than elsewhere, so that in this circle we have the nearest approach to the formation of an image of the point *D* by all the rays which are reflected from the zone of finite width *AB*, *A'B'*. This circle is called ***the circle of least confusion.*** We will next determine its position and radius.

Let x', y' be the coordinates of *A* and x'', y'' those of *B*. Then the equations of *A'C* and *BG* are respectively as follows:—

$$y = -\frac{y'}{x' - 2f - a'}\,x + \frac{x'\,y'}{x' - 2f - a'} - y', \qquad (15)$$

$$y = +\frac{y''}{x'' - 2f - a''}\,x - \frac{x''\,y''}{x'' - 2f - a''} + y'', \qquad (16)$$

where, according to equation (2),

$$a' = \frac{y'^2}{2f} + \frac{y'^4}{16f^3},$$

and

$$a'' = \frac{y''^2}{2f} + \frac{y''^4}{16f^3}.$$

E is the point of intersection of these lines. Its abscissa is the distance of the circle of least confusion from the vertex of the paraboloid, and its ordinate is the radius of this circle. Hence, if we solve equations (15) and (16), to get the coordinates of their point of intersection, we shall have the quantities required. In the unreduced form the resulting expressions are somewhat complicated. If, after forming them, we put

$$y'' + y' = 2\,z,$$

$$y'' - y' = 2\,w,$$

---

* The letter *L* is omitted from the diagram, the space available not being sufficient to give it clearly. Its location is evident from the description of the diagram.

we find that they may be reduced to the following forms:—

$$VL = 2f + \frac{z^2 + 3w^2}{2f} + \frac{z^4 + 6z^2w^2 + 9w^4}{16f^3} + \frac{w^2e}{fk} + \frac{w^2g}{4f^3k}, \quad (17)$$

and,

$$LE = \frac{4w(z^2 - w^2)(4f^2 + z^2 + w^2)}{k}, \quad (18)$$

where, for brevity, we have written

$$k = 32f^4 + 4f^2(z^2 - w^2) + (z^2 - w^2)(z^2 + 3w^2),$$

$$e = -5z^4 - 2z^2w^2 + 7w^4,$$

$$g = -3z^6 - 3z^4w^2 - z^2w^4 + 7w^6.$$

If the aberration is measured from the center of curvature, we have

$$a = VL - VD = VL - 2f$$

as the value of the longitudinal aberration of the circle of least confusion. This is given directly by transposing $2f$ from the second to the first member of equation (17). The last two terms of equation (17) are very small for such mirrors as are used for reflecting telescopes and may be omitted without material error. Neglecting them, we have

$$a = \frac{z^2 + 3w^2}{2f} + \frac{z^4 + 6z^2w^2 + 9w^4}{16f^3}, \quad (19)$$

which is a very approximate expression for the longitudinal aberration of a zone of width $2w$ and mean radius z of a parabolic mirror whose principal focal length is f.

Equation (2) is a special case of the one last given. When an infinitely narrow zone is taken, w may be put equal to zero; the omitted terms vanish, and equation (19) reduces to the form of equation (2). Further, the diameter of the circle of least confusion becomes evanescent along with w, as will be seen from a consideration of equation (18).

CASE V. *Point-source of light situated upon the axis at a distance d from the vertex, the zone being of finite width.*

Let the aberration be measured from a point on the axis at a distance h from the vertex. Then the equations of the reflected rays $A'C$ and BG are like (15) and (16), except that $2f$ is replaced by h and the aberrations a' and a'' now have the complete form of equation (12). The method here is precisely the same as for the preceding case. The results are

$$VL = \frac{fd}{d-f} + \frac{z^2 + 3\,w^2}{2\,(d-f)} + \frac{z^4 + 18\,z^2\,w^2 - 3\,w^4}{16\,f^2\,(d-f)} + \frac{3\,(-z^2\,w^2 + w^4)}{2\,df\,(d-f)}, \qquad (20)$$

and

$$LE = \frac{4\,w\,(z^2 - w^2)\,(4\,f^2 + z^2 + w^2)}{t}, \qquad (21)$$

where in the value of VL we have omitted the terms which are insensible in all practical cases. The several omitted terms are those corresponding to the last two terms of equation (17) and like them contain the factor w^2 in their numerators, while their denominators are at lowest of the order f^4.

In the denominator of (21), for brevity we have put

$$t = 16\,f^3\,d + 4\,f\,(z^2 - w^2)\,(3\,f - d) + (z^2 - w^2)\,(z^2 + 3\,w^2).$$

From equation (21) it will be seen that the diameter of the circle of least confusion becomes evanescent along with w.

If the aberration is measured from a point upon the axis at a distance h from the vertex of the paraboloid, we shall have for its value

$$a = VL - h. \qquad (22)$$

VL being given, in general, by equation (20) and h by (13). When the aberration is measured from the center of curvature the last equation becomes

$$a = VL - 2\,f. \qquad (23)$$

Equations (1) and (2) may both be obtained from (23) by giving to w, z, and d in VL values corresponding to the conditions imposed in the derivation of (1) and (2). In each case the zone then becomes infinitesimal in width. Hence $w = 0$, and we may put $z = y$. When the light is placed at the foot of the normal, *i. e.* at E in Figure 1,

$$d = x + 2\,f,$$

and in accordance with these circumstances equations (20) and (23) give

$$a = \frac{y^2}{4\,f}.$$

When the light is fixed at the center of curvature, *i. e.* at D in Fig. 1,

$$d = 2f,$$

and the same equations give

$$a = \frac{y^2}{2f} + \frac{y^4}{16f^3}.$$

MT. HAMILTON, CALIFORNIA, October 22, 1902.

OBSERVATIONS OF THE ECLIPSED MOON, OCTOBER 16, 1902.

BY ROSE O'HALLORAN.

The atmosphere here was very favorable to observation during the total phase of the recent lunar eclipse, which occurred on October 16th, in accordance with astronomical forecast. Some minutes before its symmetry was noticeably impaired, the east limb of the Moon was dimmed by the terrestrial shadow, which within half an hour had successively submerged *Grimaldi, Aristarchus, Kepler, Gassendi,* and *Tycho.* Cirrus clouds flitted by during the half-moon phase, and the crescent was formed before the shadowed surface became discernible. A narrow semicircular strip round the limb was first suffused with the glow of refracted sunlight, wreathing the dark terrestrial hemisphere, and large tracts adjacent to *Tycho,* where lunar seas are scarce, were soon included in this interesting illumination. Though familiar with descriptions of our satellite when eclipsed in recent and former years, the color was more vivid than I anticipated, and, telescopically, it was distinctly pink.

At 9:16 P. M. the shadow was over *Mare Crisium* and the crater *Petavius,* but for some minutes after totality the foreshortened limb west of these features shone with a dull white light. This was succeeded by a luminous pink hue that could not be classed as either coppery or chocolate-colored. Probably it was caused by a mingling of white light with unusually red rays from the atmospheric aureole. At first the central portion of the disk seemed to be shrouded from this beacon of totality, but before long the seas were discernible, even without magnifying power. If an observer were uninfluenced by known facts, the telescopic view was that of a translucent sphere whose central fires gleamed out more or less through the surface, according to the thickness of the crust. The white streaks so conspicuous at full moon were discernible and conveyed less impression of translucency than the other tracts, which were salmon-colored. The seas were in contrast to both, resembling a dull gray substance on which red light is cast. As the eclipsed orb advanced more centrally, its pink color declined and the time-honored coppery light held full sway for about half an hour. At this stage, but for the familiar outlines of the seas, the Moon seemed like a dusky intruder among the small stars of *Pisces* that shone so brightly through the shadow depths. In color it bore little resemblance to the ashen surface visible when the Moon is young. Before the end of totality the brighter hues reappeared, the pink glow on the east limb as it neared sunlight giving place again to a dull white that lingered until direct rays ended the total phase.

Though no mystery attaches to the encounter between the Earth's shadow and satellite, and its scientific value is limited, still as seen here to full advantage it was an impressive fulfillment of astronomical prediction and theory not soon to be forgotten.

SAN FRANCISCO, October 21, 1902.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1903.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, P. S. T.

First Quarter,	. . . Jan. 6,	1^{h}	56^{m}	P. M.
Full Moon,	. . . Jan. 13,	6	17	A. M.
Last Quarter,	. . . Jan. 20,	3	49	
New Moon,	. . . Jan. 28,	8	39	
First Quarter,	. . . Feb. 5,	2	12	
Full Moon,	. . . Feb. 11,	4	58	P. M.
Last Quarter,	. . . Feb. 18,	10	23	
New Moon,	. . . Feb. 27,	2	20	A. M.

The Earth is at perihelion at 5 P. M., January 3d, Pacific time.

Mercury is an evening star throughout January, passes inferior conjunction with the Sun on the morning of February 2d, and becomes a morning star. It reaches greatest east elongation on January 17th, being at that time not quite 19° east of the Sun. For a few days near that date it sets at about an hour and a half after sunset, and may be seen easily in the twilight on a clear evening, and for perhaps a fortnight before time of greatest elongation it can be seen under good conditions of weather. The planet's distance from the Sun diminishes rapidly after January 17th until it reaches conjunction. It then moves rapidly away from the Sun, and on February 27th it attains greatest west elongation, not quite 27°. It may for a few days be seen as a morning star, but the conditions for visibility are not nearly as good as during January, the maximum interval between the rising of the Sun and of the planet being only a few minutes more than one hour. The greater southern declination of the planet during February more than counterbalances the effect of the greater distance from the Sun at that time. The difference in distance is due to the fact that the planet is in perihelion only a week later than the greatest east elongation of January, and it is in aphelion only nine days after the west elongation in February.

Mercury while still moving eastward passes 1° 47′ south of *Saturn* on January 5th. Both planets are then almost too near the Sun to be seen easily, unless weather conditions are very favorable. After both planets become morning stars there is another conjunction on February 13th. There is also a conjunction between *Mercury* and *Venus* on January 25th, after *Mercury* has begun to approach the Sun, *Mercury* passing 3° 20′ north of *Venus*.

Venus is now an evening star, having passed inferior conjunction with the Sun late in November. On January 1st it remains above the horizon only half an hour after sunset; but this interval increases to a little more than an hour by the end of the month, and at the end of February it is nearly two hours. On account of its greater brightness *Venus* can be seen when at a much smaller distance from the Sun than can *Mercury*, but it will not be an easy object during the early days of January. On the afternoon of January 9th it is in conjunction with *Saturn*, passing a little less than 1° south of the latter. The relative motions of *Venus, Mercury*, and *Saturn* during the early days of January are very interesting, but the planets are too near the Sun for easy observation. On the afternoon of January 30th *Venus* is also in conjunction with Jupiter, passing to the south, and still nearer than it did to *Saturn*,—so near that both planets can be seen together in the field of view of a small telescope.

Mars rises a little before midnight on January 1st, at about $10^h\ 30^m$ on February 1st, and before nine on February 28th. It moves 10° slowly eastward and southward among the stars in the western part of the constellation *Virgo* until February 15th. On that date it becomes stationary, and then begins to retrograde. Its actual distance from the Earth in miles diminishes from one hundred and seventeen millions, on January 1st, to ninety millions, on February 1st, and to sixty-nine millons, on March 1st, and there will be a corresponding increase in brightness, so that toward the end of the period the planet will become quite conspicuous and the principal feature of the eastern sky late at night.

Jupiter is an evening star in January, and remains so until February 19th, when it comes to conjunction with the Sun and becomes a morning star. It is far enough away from the Sun throughout January to be seen easily in the evening, setting about three hours after sunset on January 1st. The interval diminishes about one half during the month, and after the first few days of February the distance between planet and Sun becomes too small for visibility of the planet after sunset.

Saturn is also an evening star on January 1st, but is much nearer the Sun than is *Jupiter*. It then sets less than an hour and a half after sunset, and, being much less bright than *Jupiter*, it will not be a conspicuous object. It passes conjunction with the Sun on January 20th, and becomes a morning star. By the end of February it rises about an hour and a half before sunrise.

Uranus is a morning star, not far enough away from the Sun for naked-eye view until late in February.

Neptune is in the western sky in the evening. It is in *Gemini*, but too faint to be seen without a telescope.

OBSERVATIONS OF THE TOTAL ECLIPSE OF THE MOON, OCTOBER 16, 1902.

The total lunar eclipse of October 16, 1902, was observed at the Students' Observatory of the University of California, by the students in Practical Astronomy. Some of these have had but little experience in observational work, and their results have consequently been given smaller weights. The weights have been assigned in a somewhat arbitrary manner, from consideration of experience of the observers, instruments used, etc. The atmospheric conditions were good. The observations and results are contained in the following tabulation.

Sidney D. Townley.

Total Eclipse of Moon, 1902, October 16.

Phase.	P. S. T.	O − C.	p.	Instrument.	Observer.	Remarks.
Enters shadow	8^{h} 16.8^{m}	-0.5^{m}	2	Finder of 6″	J. D. Maddrill	Definition poor.
	17.7	+0.4	2	Surveyor's Transit	Geo. Dickie	
	16.8	−0.5	2	Alt-azimuth	M. Van Wormer	
	18.0	+0.7	2	5″ Refractor	Mrs. E. Hubbard	
	18.0	+0.7	1	Eye	Mrs. J. Koethen	Time probably taken from Mrs. Hubbard's observations.
	15.5	−1.8	0	Field-glasses	Miss E Hadley	Watch comparison uncertain.
	16.8	−0.5	3	6″-Refractor	A. F. Gillihan	
Weighted mean		−0.05				
Totality begins	9^{h} 20.5^{m}	+1.5	2	Finder of 6″	J. D. Maddrill	
	19.8	+0.8	2	Surveyor's Transit	Geo. Dickie	
	19.9	+0.9	2	Alt-azimuth	M. Van Wormer	
	20.5	+1.5	1	Opera-glasses	Mrs. E. Hubbard	
	20.5	+1.5	1	Eye	Mrs. J Koethen	
	20.8	+1.8	2	3″-Refractor	Miss G. Todd	
	22.1	+3.1	0	Field-glasses	Miss E. Hadley	Watch comparison uncertain.
	19.3	+0.3	3	6″-Refractor	A. F. Gillihan	
	21.0	+2.0	2	Finder of 3″	S. D. Townley	
	20.3	+1.3	1	Eye	Chas. Petit	
	20.6	+1.6	1	Eye	E. E. Everett	
Weighted mean		+1.22				
Totality ends	10^{h} 48.4^{m}	+0.5	2	Finder of 6″	J. D. Maddrill	
	48.1	+0.2	3	6″-Refractor	A. F. Gillihan	
	48.7	+0.8	2	Finder of 5″	S. D. Townley	Uncertain, — for 2 min. preceding light was coming fast,—totality certainly over by this time.
Weighted mean		+0.46				
Leaves shadow	11^{h} 49.4^{m}	−0.3	2	Finder of 6″	J. D. Maddrill	
	49.3	−0.4	3	6″-Refractor	A. F. Gillihan	
	49.9	+0.2	2	Finder of 3″	S. D. Townley	
Weighted mean		−0.20				

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NOTICES FROM THE LICK OBSERVATORY.*

Prepared by Members of the Staff.

Comet *b* 1902 (Perrine).

This comet is proving to be of more than usual interest, by reason of its rapidity of motion, its brightness, the long duration of its apparition period, and its close approach to the planet *Mercury*.

As seen from the Earth, at the time of discovery, the comet was moving slowly northward and westward, but the first calculation of its orbit showed that its motion would rapidly increase and that it would pass within about thirty-five millions of miles of the Earth on about the 8th of October. As it was also coming toward the Sun, its brightness would increase rapidly, reaching its maximum at the time of nearest approach to the Earth, provided, that is, that it was shining by reflected sunlight.

Assuming that the brightness at discovery was that of a 9th-magnitude star, its theoretical brightness on October 8th should have been about that of a 5½-magnitude star, and should then have diminished slowly.

Observations made here show that the comet somewhat exceeded its theoretical brightness, being easily visible to the naked eye as early as September 24th, and that its light did not diminish as fast in the latter part of October as the theory of reflected light required. This will appear from a few estimates of its brightness taken from my observing notes.

Sept. 24. Comet as bright as 6.1 magnitude star near south following. Easily visible to naked eye.

Oct. 3. Comet fully as bright as 5th magnitude star.

Oct. 14. Comet passed between 109 and 110 *Herculis*. Very little fainter than these stars. Certainly not a half magnitude. [The Harvard Photometry gives the magnitudes of 109 and 110 *Herculis* as 3.9 and 4.2, respectively.]

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* Lick Astronomical Department of the University of California.

Oct. 21. Comet near a star 5.9 magnitude, and is at least a magnitude brighter.

Oct. 27. Comet fully as bright as 5th magnitude.

Nov. 4. Comet still easily seen with naked eye, though very low in the sky.

While there is thus evidence that the comet's light is not all reflected light, there have been so far no erratic variations in its brightness such as sometimes characterize a comet on its approach to the Sun.

The comet's approach to the Earth is closer than the average, but not sufficiently close to be worthy of special remark, but the close approach that Mr. F. E. Seagrave has found it will make to the planet *Mercury* on November 29-30th is most unusual and of great interest. According to the best published ephemeris of the comet, the distance separating it from the planet will not greatly exceed two millions of miles at the time of closest approach.

Professor Pickering points out that careful observations made of the comet after November 29th will afford the means of determining the effect of the disturbance of its motion by *Mercury* with such accuracy that a good value of the mass of planet may be derived. Unfortunately the comet passes the Sun on November 26th, and at the time of nearest approach to *Mercury* it will still be so close to the Sun that for a number of days accurate observations will be impossible. Observers in the southern hemisphere, however, will have a good opportunity to secure observations later on—for not the least remarkable feature of this comet is the great length of its apparent path through the sky. Discovered in $3^{h}\ 18^{m}$ Right Ascension, and 34° 39′ North Declination, it moved north and west till it reached its maximum North Declination of 57° on September 30th. At that time its Right Ascension was $23^{h}\ 34^{m}$. Still continuing its westward motion, it turned also toward the south, and on November 4th was observed here in $17^{h}\ 9^{m}$ Right Ascension and —8° 10′ Declination. According to the ephemeris given by Strömgren in *A. N.* 3821, the southwesterly motion continues until January 19, 1903, by which time the comet's position will be 11h 18m Right Ascension and —46° 27′ Declination. It then turns to the northwest, and by March 3, 1903, the last date of the ephemeris, it has reached 6h 35m Right Ascension and —11° Declination. At this time its theoretical brightness is still 0.6 that at discovery, and therefore it should be easy to observe until the end of March at least.

In view of its close approach to *Mercury*, and of the long duration of visibility of the comet, it seemed desirable to have a set of elements that would represent its motion with more accuracy than could be expected of the preliminary elements.

I therefore computed a set of parabolic elements based on the discovery position and my own observations made on October 2d and November 1st.

The elements had been derived and an ephemeris planned when the *Astronomische Nachrichten* containing STRÖMGREN'S ephemeris reached me. For comparison I give the two sets of elements here:—

	STRÖMGREN.		AITKEN.	
T =	1902, Nov. 23.88925 M. T. Berlin.		Nov. 23.85514 Greenwich M. T.	
ω =	152° 57′ 28″.2	1902.0	152° 57′ 50″.3	1902.0
Ω =	49 21 7 .5		49 21 17 .3	
i =	156 21 9 .8		156 21 5 .1	
$\log q$ =	9.603246		9.603212	

Reduced to Greenwich mean time, STRÖMGREN'S T becomes Nov. 23.85204. Evidently the two sets of elements are so nearly identical that it would be waste of time to compute an ephemeris from mine.

It is hoped that in the next number of these *Publications* we may be able to reproduce some of the fine photographs of the comet that have been secured here by Mr. R. H. CURTISS.

November 12, 1902. R. G. AITKEN.

OBSERVATIONS OF δ *EQUULEI.*

On account of the shortness of its periodic time and by reason of its forming a determinate connecting link between the visual and spectroscopic binaries, δ *Equulei* may be regarded as the most interesting of all the double stars. The early determinations of its orbit gave about 11.45 years as the time of revolution, but the observations made within the past three years show that this value is erroneous, and they further make it evident that the true period is not far from 5.7 years. This is shorter by nearly half than that of any other visual double star.

The spectrum of δ *Equulei* is not constantly the same. There are relative shiftings of the lines which make them appear broader at some epochs than at others. This is due to the relative motions of the two stars. The variations in the spectrum, so far as they have been observed, are perfectly in accord with the short period of 5.7 years, but they do not agree at all with the longer one.

The first orbits obtained for this binary, those having periods of about 11.45 years, are nearly circular. In deriving them the computers assumed that the companion receded to about equal apparent distances from the principal star on either side of it, and that the motion was in a plane having, as is true, a very high inclination. The apparent ellipse which they obtained was very elongated, and the principal star was near its center. This corresponds to a nearly circular orbit, and to changes in the apparent distance which should take place very nearly in the manner of simple harmonic motion. The observations secured since the summer of 1899 show conclusively that the apparent distance does not change in this manner. Between October, 1899, and July, 1900, the distance decreased far more rapidly than was expected. On the first of these dates it was about one third of a second; on the last Professor AITKEN found it too small for exact measurement with the great refractor. It was then much less than a tenth of a second.

During the summer of 1901 the distance increased to about 0″.15 and then decreased again. By the middle of December it had become so small that the star appeared nearly or quite round even under the most favorable conditions. These variations of distance, with a maximum of about 0″.15 on one side of the principal star and of about 0″.40 on the other, are fatal to the old hypothesis that the period of this pair is about 11.45 years, and they are entirely in accord with the theory that the period is about 5.7 years.

My measures of this pair to the middle of August, 1901, are given in Volume V of the *Publications of the Lick Observatory.* Those secured subsequently are given below. Professor AITKEN has also measured this star on some of the same nights, and when this was done we have taken the precautions mentioned in his accompanying article to render our results wholly independent. All the measures have been made with the 36-inch refractor. The powers used are indicated in the last column. The eye-piece giving a power of 2400 is the very excellent one that we constantly use on the 12-inch telescope, where it has a power of somewhat more than 600. A new adapter was made to enable us to use it in measuring this star with the large telescope last year, when the distance was becoming so small.

MEASURES.

1901.715	206°.1	0″.09	1900
.742	205 .7	0 .08	1500
.756	208 .0	0 .07	1900
.778	206 .0	<0 .10	1500
.781	206 .0	0 .07	2400
.793	198 .2	0 .05	2400
.833	194 .1	0 .05 est.	2400
.853	194 .7	0 .05 est.	2400
.890	With power 1000 the image is apparently round. With power 2400 there appears to be a very slight elongation in the direction 200°, but the distance appears to be not so great as 0″.05. Seeing good.		
.968	With power 2400 elongation uncertain. Distance regarded under 0″.05, and certainly too small to be measureable. Turned at once to *κ Pegasi*. Its distance was less than 0.10, yet its elongation was easily seen.		
1902.389	25°.8	<0″.10	2400
.463	38 .1	0 .07 est.	2400
.545	46 .9	0 .08	2400
.597	42 .8	0 .09	1500
.638	36 .2	0 .12	2400
.695	43 .1	0 .12	1500
.723	41 .1	0 .13	2400
.753	35 .9	0 .16	2400
.788	39 .1	0 .16	2400
.827	38 .2	0 .15	1500

MT. HAMILTON, NOV. 14, 1902.

W. J. HUSSEY.

FURTHER MEASURES OF δ *EQUULEI*, OΣ 535.

In a note on this interesting binary star published in number 79 of these *Publications*, I gave two measures made in May, 1901, which showed that the distance between its two components was increasing, after the close approach observed in the autumn months of 1900. The pair was closely followed by Professor HUSSEY and myself until December 19th of last year, and our observations left no doubt of the fact that the distance between the components reached a maximum value of about 0″.15 in June, 1901, and then slowly diminished until in November and December it was so small that the combined disk gave only the slightest indication of elongation when examined with the highest-power eye-pieces of the 36-inch telescope.

My first opportunity to observe the star this year under fairly good conditions came on morning of June 8th. At that time it was certain that the image was elongated, though the distance was too small to make the measure of the direction of elongation very accurate. Since that date Professor HUSSEY and I have measured the pair on a number of nights, and have found the distance to be increasing until it has become a fairly easy pair to observe with the 36-inch on good nights. At the time of my last observation the two components were distinctly separated at moments, and the distance between their centers was certainly as great as 0″.15.

My observations to October 31, 1901, have been published in Lick Observatory Bulletin No. 11. Those made since then are as follows:—

Date.	Position-Angle.	Distance.	Eye-piece.	Seeing.
1901.833	Elongation too slight for good measures.	. . . .	2400	3
.852	194°.5	0″.05 ±	2400	4
.967	No certain elongation.	< 0″.05	2400	4
1902.433	70°.0 ±	< 0 .10	1900 2400	3
.597	35 .7	0 .10	2400	3
.638	38 .3	0 .12	2400	4
.684	33 .6	0 .14	1900	3
.753	34 .2	0 .13	2400	3
.788	36 .6	0 .14	2400	3
.794	34 .9	0 .17	1500	3

On the three nights in 1901, Professor HUSSEY was with me. We examined γ *Equulei* immediately after making our measures on the second night. Its image was perfectly round at the best moments, and when distorted by atmospheric disturbances, the slight apparent elongation was nearly perpendicular to the position-angle measured for δ *Equulei.* On the third night, after examining δ *Equulei,* we turned at once to κ *Pegasi.* The elongation in this pair was unmistakable, though, from measures made here and elsewhere, it is certain that the distance was not over 0".08. On these nights as on the others when we examined this star together, we used every precaution to make our work independent. When measures were made, one would make the settings, the other read the circle and record, so that the observer could know nothing about his measures till they were completed and on record. On several nights a third person read the circle and recorded for both observers.

From the observations made here since the summer of 1899, it is safe to conclude that the revolution period of 5.7 years which Professor HUSSEY found from his study of the orbit, is very close to the truth. It also appears that the plane of the orbit is not exactly in the line of sight, but that the apparent motion is in a very narrow ellipse. The inclination of the orbit plane probably is as great as 80°, but to determine this and the remaining elements of the orbit with precision will require careful and continuous measures during the next three years.

R. G. AITKEN.

November 13, 1902.

THE *LEONIDS* OF 1902.

Watch for *Leonids* was kept by the writer during the nights of November 14th and 15th, a total number of nineteen being seen on the first night and twenty-nine on the second. Except for the moonlight, the general conditions were very favorable. A few light clouds came over at times, but they were not enough to affect seriously the count of meteors. The observer's attention was fixed on the Sickle, and all meteors which certainly emanated from the radiant were counted as *Leonids,* doubtful cases being classed with those which were surely not *Leonids.* In brightness, the *Leonids* observed ranged from one which was equal to *Sirius* to some of the fifth magnitude. Six or eight were as bright as *Regulus.* Of those which were seen at a distance of say thirty degrees or more from the radiant, nearly all must have been at least as bright as the third magnitude.

Following are the data of the observations:—

Astronomical Date.	Pacific Standard Time.	*Leonids.*	Other Meteors.	Remarks.
1902. Nov. 14.	13^h01^m to 14^h00^m	2	5	
	14 00 15 00	5	3	Clouded over at $15^h\ 00^m$
	15 33 16 00	3	4	Perfectly clear.
	16 00 16 30	3	1	
	16 30 17 00	2	2	Sky 7/10 cloudy at $16^h\ 30^m$ Clear again in five minutes.
	17 00 17 30	4	3	
	Total in $3^h\ 56^m$	19	18	
Nov. 15.	13 09 13 30	1	0	Light clouds at times during the night, but they did not interfere.
	13 30 14 00	1	0	
	14 00 14 30	0	2	
	14 30 15 00	3	0	
	15 00 15 30	0	0	
	15 30 16 00	6	1	
	16 00 16 30	7	0	
	16 30 17 00	8	0	
	17 00 17 30	3	0	Clouded over at $17^h\ 30^m$
	Total in $4^h\ 21^m$	29	3	

The relatively large number of other meteors on the first night was not due to the inclusion of doubtful cases. The observing conditions were the same on both nights. From the roof of the main building there was an unobstructed view of the sky from the zenith to the eastern horizon. As much of the space around the radiant was covered as the eye can take in at one time.

JOEL STEBBINS.

AN UNUSUAL TRIPLE STAR.

In the latter part of September I discovered a triple star which is unlike any other that I have seen. The differences in the magnitudes of the three stars are not very great and the configuration is that of an almost perfect equilateral triangle.

The means of the measures of distance on two nights with the 36-inch telescope are as follows:—

A B	1″.55.
B C	1″.47.
C A	1″.61.

Such triples, had we more of them, affording a gradation of distances from those which are very small to those which amount to several seconds of arc, would enable investigations relating to the personal errors in the measurement of position-angle to be undertaken with a promise of reaching more conclusive results than have characterized such investigations in the past.

This star is D. M. + 49° 95. Its position, derived from the Bonn A. G. Catalogue, where its magnitude is given as 8.9, is as follows:—

$$\left.\begin{array}{l}\text{R. A.} = 0^{h}\ 22^{m}\ 21^{s}.14. \\ \text{Decl.} = +49^{\circ}\ 28'\ 10''.9.\end{array}\right\}\ 1900.0.$$

W. J. HUSSEY.

ECLIPSE OF THE FIRST MOON OF *JUPITER*.

[Dr. E. S. HOLDEN has kindly sent us the following letter received by him, as it will be of general interest.—*Publication Committee.*]

ST. LOUIS, MO., Oct. 21, 1902.

Dear Sir:—The transits of the moons and their shadows across the disk of the planet *Jupiter* have always been interesting phenomena to me, and I frequently watch them when the atmosphere of smoky St. Louis will permit.

On examination of the ephemeris a few days ago, I found that the shadows of the moons I and III would both be visible on the evening of October 19th. Going to my observatory on this date, and bringing *Jupiter* into the field of my 6½-inch I found both shadows on the disk.

As the position of shadows indicated that I appeared on the disk last, and further examination of the almanac showed it would pass off first, I was interested to know just how, or in what position the shadows would be in when passing each other. After waiting some seventy minutes the shadow of I merged with shadow of III, and at last became lost to view, although the indications were that it would pass slightly below the shadow of III; but owing to bad atmosphere this could not be definitely determined by observation of the shadows. In the mean time I had called my son's attention to the passing show in order to verify the question. We now turned our attention to the moons, and found that previous to the shadow contact moon I was bright, but when we lost the shadow we found that the moon was losing light rapidly, and at 8:30 the moon became a very faint point of light, showing conclusively that we had observed a partial eclipse of moon I in the shadow of moon III.

I might add that moons II, III, and IV remained bright all this time and that moon I regained its brightness about 8:40.

The eclipse was of very short duration at best, and not having been fortunate enough to observe one previous to this time I write this for the benefit of others who may be interested and ask if it be an unusual occurrence in so far as being observed frequently. Yours truly,

3021 Eads Avenue. L. Bartlett.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in the work of this department. Communications to this end may be sent to FRANK SCHLESINGER, International Latitude Observatory, Ukiah, California.

Co-operation in Line-of-Sight Observations.—The number of astronomical enterprises calling for the co-operation of several observatories or observers is steadily increasing. The latest addition to the list relates to the determination of velocities in the line of sight with the spectroscope. It has been recognized for some time that observations of this kind may be subject to considerable systematic errors. In the case of variable velocity in the line of sight, for example, no safe conclusions can be drawn from the results given by different observers unless allowance is made for systematic differences. An obvious safeguard is for each observer to test his instrument by observing some body, like the Moon or the planets, whose velocity is well known in advance. Such tests have occasionally been made in the past by observers with the spectroscope, but perhaps not so often as would seem desirable. In other kinds of "observations of position," with the heliometer, for example, the observer who aims at the highest precision spends a considerable fraction *of each night* in controlling the adjustment of his instrument. Great care is no less necessary with the spectroscope, especially since experience has shown that an instrument ordinarily capable of determining velocities with a probable error well under one kilometer may, for one reason or another, occasionally become deranged so as to yield velocities ten kilometers in error.

Professor E. B. FROST, of the Yerkes Observatory, has just proposed a plan for the investigation of systematic errors which in all likelihood is destined to be of much importance in the history of the subject. The observatories at Potsdam, Poulkova, Meudon, Cape of Good Hope, Cambridge (England), the McMillin (Ohio), the Yerkes, and the Lick are represented in the scheme, so that all the observers at present engaged in this kind of work will take part. Ten stars, to be known as "fundamental velocity stars," are to be observed at least three times a year by each observer, and the results are to be promptly published, together with all collateral data. The selected stars are well distributed in Right Ascension and in Declination; they range four magnitudes in brightness, and the spectral types also differ somewhat. Known spectroscopic binaries, with one exception, have been excluded from the list. This plan is regarded as a preliminary one. "It is to be hoped," writes the proposer, "that the experience of this simple plan of co-operation may be satisfactory enough to lead to its further development in the future."

The Parallax of the Sun from Spectroscopic Observations.—It is a fascinating thought that the parallax of the Sun can be determined by means of the spectroscope. In order to compute the linear velocity of the Earth in its orbit we must first know the distance of the Sun. Conversely, if we measure the Earth's velocity, we can compute the Sun's distance (and therefore its parallax) from the equation:—

The Sun's mean distance = the Earth's mean velocity × a constant.

This constant is known with extreme accuracy. Now, if any star near the zodiac be observed with the spectroscope at the two seasons when its longitude differs from that of the Sun by 90°, we can deduce not only the velocity of the star in the line of sight, but the mean velocity of the Earth in its orbit as well. These ideas have no doubt been entertained by spectroscopists ever since the practical demonstration of the soundness of DOPPLER's principle, but they have not been put into effect because until quite recently it has not been possible to make the observations with sufficient accuracy. In connection with the plan of co-operation which is the subject of the preceding note, Sir DAVID GILL, Director of the Cape of Good Hope Observatory, has thrown out the suggestion that, "at each observatory some star should be selected to be observed nearly throughout the whole year, so as to determine the mean velocity of the Earth's motion independently by spectroscopic means—in other words, to determine the solar parallax by spectroscopic methods. This should give us a tolerably sound measurement of the fundamental accuracy of our work." It is to be hoped that this suggestion will be generally adopted. It is not impossible that the result of such observations would be valuable as a contribution to our knowledge of the Sun's distance as well as for the reason given by

Sir DAVID GILL. Two observations, taken at two opposite seasons, of a properly chosen star, will differ by as much as 59.7 kilometers per second on account of the Earth's motion. Several spectroscopes have at the present time reached or surpassed an accuracy corresponding to a probable error of half a kilometer for a single determination of a velocity. This means that in order to reduce the probable error of the Sun's parallax to 0".01 about two hundred observations would be necessary. As these observations would be distributed among several observatories, the expectation would perhaps not be unwarranted that systematic errors would not greatly influence the result, especially when it is remembered that the observations are *differential,* and that any error which is constant for a given star would not affect the result. Furthermore, special precautions like the following might be adopted for this work: (1) The star to be observed should have a longitude near six hours or eighteen hours in order that in the spring and in the fall its longitude will differ from that of the Sun by 90°. In this way observations at extreme temperatures may be avoided. (2) Without being too far from the zodiac the star should have such a declination as to pass near the zenith. (3) The star should have the best kind of spectrum for this work (SECCHI's Type II). (4) As bright a star as possible should be chosen in order to make the exposures short. (5) The star should always be observed at nearly the same hour-angle, and therefore at nearly the same zenith-distance.

Change in the Spectrum of Nova Persei.—*Nova Persei* has steadily diminished in brightness, until now it is fainter than the ninth magnitude; that is, it emits less than the one four-thousandth part of its light at the height of its glory, in February, 1901. Ordinary spectroscopic observations upon such an object are, of course, extremely difficult, but Professor BARNARD of the Yerkes Observatory was able to show in a simple and ingenious way that the spectrum had undergone an important change toward the beginning of October. Up to that time repeated examinations of the focal-scale attached to the great 40-inch telescope showed no difference between the *Nova* and an ordinary star. But on October 6th, and some succeeding dates, Professor BARNARD found that the focal length was five or six millimeters longer for the *Nova* than for other faint stars. At the same time he noted a change in color from white to bluish-white. Professor BARNARD was led to make these observations by his earlier work on planetary nebulæ, which the *Nova* much resembles. It was in their case that he first noticed a measurable difference in focus as compared with the majority of stars. The theory of this difference is quite simple, arising from the imperfect achromatism of the objective. If we should focus in succession upon luminous objects emitting monochromatic light, we should find a regular and gradual change in focal length as we pass from one color to its neighbor in the spectrum. Of course, such a change in focus is not appreciable in a small telescope. The Yerkes telescope has a focal length of 62 feet, and is therefore pre-eminently fit for such observations.

On November 29th, Comet 1902 *b* (PERRINE) passed within two million miles of *Mercury*. As the perturbation of the comet is comparatively great at such a small distance, it is not improbable that a thorough discussion of the comet's orbit will throw additional light on the question of *Mercury's* mass. This quantity is at present quite indeterminate, more so than the mass of any other planet. A change of twenty or thirty per cent from the usually adopted value is not impossible. Observations of this comet therefore assume unusual importance.

Dr. CARL W. WIRTZ has carried out an extensive triangulation of the *Hyades* with the six-inch heliometer at the Bonn Observatory. This instrument was made by MERZ and MAHLER sixty years ago. The triangulation includes sixty-nine stars and extends over the well-known V in *Taurus* and over an equal portion of the sky immediately south. The whole area included is about eighteen square degrees, and it is the greatest single area ever triangulated. The reason for extending the work to such limits is found in the community of proper motion which attaches to nearly all the stars in the region. Dr. WIRTZ's work will, after the lapse of some years, no doubt occupy the same relation to this group as BESSEL's work does to the *Pleiades*, or WINNECKE's to *Præsepe*.

Professor WILHELM FOERSTER, Director of the Royal Observatory at Berlin, announces his intention of retiring next year. He will, however, still retain his professorship in the university.

The authorities of Williams College, Williamstown, Mass., have named Professor MILHAM as successor to the late Professor SAFFORD in the directorship of the Field Memorial Observatory at that institution.

Dr. RUSSELL TRACY CRAWFORD has resigned his place in the Berkeley Astronomical Department of the University of California, to accept a position on the examining force of the United States Civil Service Commission.

A brother of Director VAN VLECK, of the Wesleyan University Observatory, at Middletown, Conn., has given the sum of $40,000 to the university for the erection of a new observatory.

ALEXANDER KOWALSKI, astronomer at the Poulkova Observatory, died on July 6th last, at the age of forty-four years. He was born at Kasan, where his father was director of the observatory of that city. ALEXANDER KOWALSKI had been connected with the Kasan Observatory from 1882 to 1894, at which latter date he accepted a call to Poulkova. At Kasan he took part in the observations for the Astronomische Gesellschaft Catalogue of Stars (Zone 75° to 80°), in observations with the prime-vertical, and in the latitude-variation work. At Poulkova he was chiefly concerned with a new catalogue of 1000 stars which has just been completed. This catalogue is the first, we believe, to be based upon observations with the registering micrometer.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS. HELD IN THE ROOMS OF THE SOCIETY, NOVEMBER 29, 1902, AT 7:30 P.M.

President PERRINE presided. A quorum was present. The minutes of the last meeting were approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED NOVEMBER 29, 1902.

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Mr. WM. H. SMYTH	101 Sansome St., S. F., Cal.

to take effect January 1, 1903.

It was, upon motion,

Resolved, That the Librarian be instructed to have prepared a manuscript catalogue of the books in the Library, and that an expenditure of not to exceed $50, from the interest of the Montgomery Library Fund, be authorized for that purpose.

The report of the Committee on Membership was accepted, and the Committee, consisting of Messrs. CHAS. S. CUSHING (Chairman), CHAS. BURCKHALTER, and ARMIN O. LEUSCHNER, was authorized to proceed with the carrying out of its recommendations.

The Secretary was authorized to furnish to the members of the Publication Committee, for reference purposes and as a loan, such copies of the back numbers of the *Publications* as they may need to complete their sets.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE LECTURE HALL OF THE CALIFORNIA ACADEMY OF SCIENCES, NOVEMBER 29, 1902, AT 8 O'CLOCK P. M.

The meeting was called to order by President **PERRINE**. A quorum was present. The minutes of the last meeting were approved. The Secretary read the names of new members elected.

The following papers were presented:—

The Longitudinal Aberration of a Parabolic Mirror, by Professor W. J. **HUSSEY**.
Observations of the Eclipsed Moon, by Miss **ROSE O'HALLORAN**.
Planetary Phenomena for January and February, 1903, by Professor M McNEILL.
Observations of the Total Eclipse of the Moon, by Dr. S. D. **TOWNLEY**.

The Chairman then introduced the lecturer of the evening, Professor W. J. **HUSSEY**, Astronomer at the Lick Observatory. The subject of the lecture was "Recent Progress in Double-Star Astronomy." After giving a short historical sketch of this branch of the science, Professor **HUSSEY** presented in tabular form the results obtained by all observers, from the first observations by **HERSCHEL** down to those of the present year, and impressed his interested audience with the great difficulties encountered in obtaining accurate measures of close pairs of double stars. After exhibiting a number of slides of double-star orbits and of astronomical objects the lecturer answered various questions put by members of the Society.

The meeting then adjourned.

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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London, England, British Museum.
London, England, Royal Astronomical Society.
London, England, 3 Verulam Bldgs., Gray's Inn. The Nautical Almanac.
Lund, Sweden, University Observatory.
Madison, Wisconsin, Washburn Observatory.
Madrid, Spain, Royal Observatory.
Marseilles, France, Observatory.
Melbourne, Victoria, Observatory.
Mexico, Mexico, Sociedad Cientifica "Antonio Alzate."
Milan, Italy, Royal Observatory.
Moscow, Russia, University Observatory.
Munich, Germany, Royal Observatory.
Naples, Italy, Royal Observatory.
New Haven, Connecticut, Yale University Observatory.

New York, New York, American Mathematical Society.
New York, New York, Columbia University Observatory.
Nice, France, Observatory.
Northfield, Minnesota, Carleton College Observatory.
Oxford, England, Radcliffe Observatory.
Oxford, England, University Observatory.
Padua, Italy, Astronomical Observatory.
Paris, France, Bureau of Longitudes.
Paris, France, National Observatory.
Paris, France, Rue Cassini 16, Société Astronomique de France.
Philadelphia, Pa., 105 South Fifth St., American Philosophical Society.
Potsdam, Germany, Astrophysical Observatory.
Prague, Austro-Hungary, University Observatory.
Pulkowa, Russia, Imperial Observatory.
Rio de Janeiro, Brazil, Observatory.
Rome, Italy, Observatory of the Roman College.
Rome, Italy, Specula Vaticana.
San Francisco, California, California Academy of Sciences.
San Francisco, California, Technical Society of the Pacific Coast.
Stockholm, Sweden, University Observatory.
Strassburg, Germany, University Observatory.
Sydney, New South Wales, Observatory.
Tacubaya, Mexico, National Observatory.
Tokio, Japan, University Observatory.
Toronto, Canada, Astronomical and Physical Society of Toronto.
Toulouse, France, Observatory.
Turin, Italy, Observatory.
University Park, Colorado, Chamberlin Observatory.
University of Virginia, Virginia, McCormick Observatory.
Upsala, Sweden, University Observatory.
Vienna, Austria, Imperial Observatory.
Vienna (Ottakring), Austria, Von Kuffner's Observatory.
Washington, District of Columbia, Library of Congress.
Washington, District of Columbia, National Academy of Sciences.
Washington, District of Columbia, Naval Observatory.
Washington, District of Columbia, Smithsonian Institution.
Washington, District of Columbia, The American Ephemeris.
Washington, District of Columbia, U. S. Coast and Geodetic Survey.
William's Bay, Wisconsin, Yerkes Observatory.
Zurich, Switzerland, Observatory.

EXCHANGES.

Astrophysical Journal, William's Bay, Wisconsin.
Sirius, Cologne, Germany.
The Observatory, Greenwich, England.

FOR REVIEW.

[See *Publications*, A. S. P., vol. VIII, p. 101.]

The Call, San Francisco, California.
The Chronicle, San Francisco, California.
The Examiner, San Francisco, California.
The Mercury, San José, California.
The Record-Union, Sacramento, California.
The Times, Los Angeles, California.
The Tribune, Oakland, California.

THE TOTAL LIGHT OF THE STARS.

By Sidney D. Townley.

While engaged in photometric work at the Lick Observatory during the past summer, a few experiments were made to determine the amount of light received from the sky at night when the Moon is not shining. This work was undertaken at the request of Director Campbell, to whom the problem was suggested by Professor Newcomb. This problem is one to which very little attention has been given, but it is nevertheless one of considerable importance, because it has a direct bearing upon the theories of the structure of the universe. The problem of the structure of the universe, after having lain dormant for nearly a century, is now again commanding the attention of investigators.

Both visual and photographic methods are applicable to the determination of the total amount of light received from the sky, and Professor Newcomb has already employed some of the visual methods, the results of which were printed in the *Astrophysical Journal* (December, 1901). The problem may be divided into two parts: first, to determine the relative brightness of different portions of the sky; and second, to determine, in terms of star-brightness, the amount of light received from a unit of sky-surface in one or more regions of the sky. Professor Newcomb's experiments were performed while spending a summer vacation in the country, where he had at his disposal only some very crude pieces of apparatus. Several methods, which I will not stop to describe, were used by him to determine the relative brightness of different portions of the sky, the conclusion being that the illumination of the Galaxy is about twice that of other portions of the sky. To solve the second part of the problem, Professor Newcomb used a concave spectacle-lens to spread out the light of a star, and then compared this image, reduced by means of dark glass, with an equal area of neighboring sky. Various stars were tried, and it was found that with the particular lens and absorbing-glass used the spread-out image of α *Pegasi* was equal in brightness to the neighboring sky. It will perhaps be sufficient to give the results of these observations, without going into the details of the reductions. The result is that a circle of non-galactic sky one degree in diameter gives 0.9 the light of a star of the fifth magnitude.

My efforts were directed almost exclusively to perfecting a photographic method. The results obtained are meager, but it is believed that a reliable method has been found.

As the light of the sky cannot be concentrated at a point, we must, if we wish to get its value in terms of the light of a star of a certain magnitude, take some means to spread out the light of the star. It was at first thought that this might be accomplished by inserting a photographic plate a few inches behind the focus of a photographic telescope. The Crocker telescope (6 inches aperture and 33 inches focus) was first used for this purpose. A rapid plate (Cramer Crown) was exposed for one hour on *Vega,* about 25 centimeters out of focus. An impression 1.9 centimeters in diameter was formed on the plate, but it was found that the light was very unevenly distributed. The impression was made up of small dark granules surrounded by lighter circles. A straight "gash" ran nearly across the center of the circle, and there were also several smaller curved "gashes." A second plate showed exactly the same pattern, which is due, I suppose, to lack of homogeneity in the glass of the lenses. Similar tests with another lens gave somewhat better results, but not sufficiently good for the purpose. This method had therefore to be abandoned.

The next method tried, and the one adopted, is indeed very simple. Both lenses were removed from the Crocker photographic telescope, and several cardboard diaphragms were made so that they could be attached to the end of the telescope-tube. An exposure of one hour was made upon *Vega* with an aperture of three centimeters, and the result was, of course, an impression on the plate of the size and form of the aperture. Exposures were then made upon the sky for equivalent lengths of time, with apertures ranging from 10 to 15 centimeters. The result should be a nearly uniform darkening all over the plate, which would receive light from an area of the sky the diameter of which would depend upon the aperture used and the distance of the plate from the aperture. If the darkening of one of these plates should be of the same intensity as the impression made by the light of *Vega,* then we would have the very simple relation,—the light received from an area of sky x degrees in diameter is equal in actinic intensity to the light received from *Vega*. After a few experiments, it was seen that the time necessary to get a set of plates—about five hours—could be greatly reduced and the effect of changing atmospheric absorption avoided by making all of the exposures on the sky at the same time. This was accomplished by mounting four camera-boxes, simply aperture and plate-holders, upon a polar axis made of a piece of wood 4×4 inches. In the very limited length of time which I had to devote to this work it was possible to obtain only a few sets of plates. All the plates of each set were, of course, developed at the same time in a large tray. In the exposures a portion of each plate was left covered by the slide in order to measure the effect of any chemical fog which might appear in the development. Several regions of the sky were used, and two stars, *Vega* and *Arcturus*. As *Arcturus* is a yellow star, only a very faint impression was obtained with a one-hour exposure; and as extreme development was necessary to bring out anything, the plates are not to be relied upon.

The intensity of the various plates has been measured by means of an excellent Lummer-Brodhun photometer, kindly placed at my disposal by the Department of Physics of the University of California. It seems hardly necessary to go into details of these measurements. Two sets of plates give, I believe, reliable results, but I am looking upon them all as merely experimental, and hope to continue the work next summer. In the first of these sets four simultaneous exposures of an hour were made upon the region of sky about half-way between γ *Pegasi* and β *Ceti*,—that is, about 40° south galactic latitude. The angular apertures used were 5° 28'.6, 6° 36'.9, 7° 16'.4, 8° 2'.6, and *Vega* was the comparison-star. The photometric measurements show the darkening of the film due to the light of *Vega* to be exactly equivalent to the darkening upon the third plate,—that is, the light from an area of rather vacant non-galactic sky 7° 16'.4 in diameter possesses the same actinic intensity as the light of *Vega*. We will have, therefore, taking the magnitude of *Vega* to be 0.2, the light received from an area one degree in diameter equivalent to the light of a 4.5-magnitude star, which is not far from the result obtained by Professor NEWCOMB, using visual methods,—namely, that the light received from a circle of non-galactic sky one degree in diameter is equivalent to 0.9 the light of a star of the fifth magnitude.

In the second set of plates *Vega* was the comparison-star, and the sky used was a portion of the Milky Way nearest *Vega.* The photometric measurement of these plates gives the light of *Vega* equivalent to that received from an area of galactic sky 5° 19′.8 in diameter. From these two sets we find galactic sky 1.9 times brighter than non-galactic sky, which is also in fair accord with the results obtained by Professor NEWCOMB, but does not agree very well with most persons' general impression of the relative brightness of galactic and non-galactic sky.

As before stated, these results are to be taken as provisional only. It is my intention to carry on the work again next summer, and it is believed that valuable results can now be obtained. I wish to express my obligations to Director CAMPBELL, who kindly placed at my disposal all material and equipment necessary to carry out the experiments.

BERKELEY, CAL., 1902, December 24.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1903.

By MALCOLM McNEILL.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter,	March	6,	$11^h 14^m$ A.M.	First Quarter,	April	4,	$5^h 51^m$ P.M.
Full Moon,	"	13,	4 13 A.M.	Full Moon,	"	11,	4 18 P.M.
Last Quarter,	"	20,	6 8 P.M.	Last Quarter,	"	19,	1 30 P.M.
New Moon,	"	28,	5 26 P.M.	New Moon,	"	27,	5 31 A.M.

The vernal equinox, the time when the Sun crosses the equator from south to north and spring begins, occurs March 21st, 11 A. M., Pacific time.

There will be two eclipses during the period March-April. The first is an annular eclipse of the Sun, on March 28th. The path of the central eclipse begins in middle Asia and runs northwest, ending in the Arctic Ocean north of Alaska. The eclipse may be seen as a partial one in the eastern part of Asia and the northwestern portions of North America. It will not be visible in the United States in general.

The second is a partial eclipse of the Moon on the evening of April 11th. Although the Moon leaves the penumbra at 7 P. M., Pacific time, it leaves the shadow more than an hour earlier; so the eclipse will not be a noticeable phenomenon in the extreme western portions of the country, but it will be well seen in the eastern portions during the early evening. The eclipse is almost total, less than three per cent of the Moon's diameter being uncovered during the middle of the eclipse, which occurs at 7^h 13^m Eastern time.

Mercury is a morning star during March and until April 10th, when it reaches superior conjunction with the Sun and becomes an evening star. For the first ten days or so of March it rises an hour or more before sunrise, and may be seen in the early morning twilight under good weather conditions. After passing conjunction its distance from the Sun rapidly increases, and toward the end of the month it is well out toward greatest east elongation. It may be seen as an evening star toward the end of the month, and on May 1st it remains above the horizon 1^h 40^m after sunset.

Venus is an evening star, and increases its distance from the Sun about 16° in their common eastward motion. On March 1st it remains above the horizon a little less than two hours after sunset, and by the end of April this interval has increased to more than three hours, and the planet does not set until nearly 10 P. M. It will be very conspicuous in the western sky in the evening, but not nearly so bright as it is when near inferior conjunction.

Mars will be the most interesting astronomical object during the present period. It comes to opposition on the night of March 28-29th, and during the whole March-April period it remains above the horizon nearly the entire night. It is brighter than it has been since the opposition of February, 1901, or will be again until the spring of 1905. At the time of opposition its distance from the Earth is a little less than sixty millions of miles. On account of the great eccentricity of

Mars's orbit, the nearest approach to the Earth varies greatly at different oppositions. It will be nearer to us by about four million miles at the present opposition than it was at the opposition of 1901; and the oppositions of 1905 and 1907 will will be still better. The motion of the planet among the stars during the two-months period is retrograde about 19°, from a position in *Virgo* not far from *Spica,* the brightest star of the constellation, to a point in *Leo* not far from *Denebola,* the second star of the latter constellation.

Jupiter is a morning star, having passed conjunction with the Sun on February 19th. It rises at about 6^h 30^m on March 1st, and at about 3 A. M. on April 30th. It is rather too near the Sun to be seen during the early days of March, but soon begins to show in the early morning twilight, and is the brightest object in the eastern part of the morning heavens. It is in conjunction with *Mercury* on the afternoon of March 18th. *Jupiter's* superior brightness will enable it to be seen in the morning twilight, but *Mercury* is so much fainter that it will not be easy to see it in its position, about three Moon's diameters south of *Jupiter. Jupiter* is in the constellation *Aquarius,* and moves 13° eastward and northward during March and April.

Saturn is also a morning star, and rises at about 5 o'clock on March 1st. By the end of April it rises shortly after 1 o'clock. As it is much less bright than *Jupiter,* it is not very conspicuous during the early days of March. It is in the constellation *Capricorn,* and during the two-months period moves about 5° eastward and northward.

Uranus rises at about half-past 2 o'clock on March 1st, and at about half after 10 at the end of April. It moves slowly eastward among the stars during March, and then retrogrades during April; but the whole motion is confined to a space about equal to the Moon's diameter. It is still in the southern extension of *Ophiuchus,* and no bright star is near enough to afford an easy means of identification.

Neptune is in *Gemini.* By the end of April it sets at about 11 P. M.

(FORTY-FIRST) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to WILLIAM R. BROOKS, Director of Smith Observatory, Geneva, New York, for his discovery of an unexpected comet on April 14, 1902.

The Committee on the Comet-Medal:
W. W. CAMPBELL,
CHAS. BURCKHALTER,
WM. M. PIERSON.

(FORTY-SECOND) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Professor CHARLES D. PERRINE, of the Lick Observatory, for his discovery of an unexpected comet on September 1, 1902.

The Committee on the Comet Medal:
W. W. CAMPBELL,
CHAS. BURCKHALTER,
WM. M. PIERSON.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

NEW SPECTROSCOPIC BINARY STARS.

During the absence of Dr. CAMPBELL from the Observatory a few results of interest have been obtained in the work with the Mills spectrograph. Three new spectroscopic binaries have been discovered,—viz., ν *Andromedæ,* π^4 *Orionis,* and σ *Geminorum.*

The first of these, ν *Andromedæ,* has very few lines in that part of the spectrum which we use, and the hydrogen line whose wave-length is 4340.634 is quite diffuse; but there are a few lines due to helium and magnesium which allow fairly accurate measurements. The radial velocity was —17 kilometers per second on October 8, 1902, —76 kilometers on November 5th, and +49 kilometers on January 14, 1903, giving a total range of 125 kilometers.

The star π^4 *Orionis* has a spectrum very similar to that of ν *Andromedæ,* but the range of velocity which we have obtained is not so great, though it is too large to allow any doubt of the star being a binary. The velocity was +43 kilometers on October 6, 1902, ± 0 on January 4, 1903, and +6 on January 12th.

The spectrum of σ *Geminorum* shows a great number of metallic lines, though they are in most cases rather ill-defined, so that measurements of its velocity are not so accurate as is the case with most stars whose spectra show numerous lines. The rather rough preliminary measurements that have been made show such a range of velocity, however, that the star is certainly a binary. On March 16, 1902, its velocity was approximately +74 kilometers, against +12 kilometers on January 12th and +9 on January 13, 1903.

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* Lick Astronomical Department of the University of California.

Another star, ϕ_2 *Orionis,* is interesting on account of its great radial velocity. Approximate measurements give + 96 kilometers on October 28, 1902, + 103 on November 24th, and + 98 on December 30th. It is not likely that the range of seven kilometers in these measurements indicates a real variability in the velocity of the star, for the plate of November 24th was taken under poor conditions and was very much under-exposed.

Approximate measurements of the plates of the spectrum of τ *Ursæ Majoris,* taken on January 22, 1900, and April 15, 1902, respectively, showed a range of five kilometers. As this was sufficient to cause suspicion of variability, Mr. STEBBINS measured both plates very carefully, and obtained the velocities — 3.8 kilometers for the first date and — 10.2 for the second, showing that the star is almost certainly a binary. A rough measurement of a later plate gives a velocity of — 4 kilometers (on December 29, 1902).

Most of the measurements of the other plates were made by Dr. H. D. CURTIS, and many of the plates were exposed by him.

H. M. REESE.

THE DIAMETER OF *TITAN.*

The statement is sometimes made in books on astronomy that the diameter of *Titan* is probably 3,000 to 4,000 miles. These values are undoubtedly too large. When the micrometer-wires of the 36-inch refractor are separated to an amount corresponding to a diameter of 4,000 miles and the image of *Titan* is placed between them, this image, when the atmospheric conditions are sufficiently good to stand very high powers, will easily be seen to be entirely inside the inner edges of both wires. When the wires are separated to correspond to a diameter of three thousand miles the image is very nearly tangent to the inner edges of both wires, from which it may be inferred that the diameter is certainly less than 3,000 miles.

During the past opposition, while measuring the relative positions of the satellites of *Saturn,* I have on several nights satisfied myself respecting the correctness of the above statements. On two nights when the seeing was particularly good I have also measured the apparent diameter of *Titan,* with the following results:—

1902, June	19	0″.60 or 2,473 miles
October	2	0 .53 or 2,332 miles

The first of these measures was made under excellent atmospheric conditions. A power of 2400 was used, and even with this very high power *Titan* presented a sharply defined disk. It is seldom that so high a power can be used for such work. The second measure was made with a power of 1000. For so small a distance this is about the minimum power that can be used to advantage.

On five nights in each of the years 1894 and 1895 Professor BARNARD measured the diameter of *Titan* with the large refractor of the Lick Observatory. His separate results, given in arc, when reduced to miles, range from about 2,100 to nearly 3,200 miles. The mean result which he obtains for the two years is 2,720 miles.

If we say that the diameter of *Titan* is about 2,500 miles we shall probably not be very much in error.

January 15, 1903. W. J. HUSSEY.

A NEW DOUBLE STAR = A. B. of Σ 1233.

Observations made with the 36-inch telescope show that the principal component of the wide pair Σ 1233 is itself a close double star. Measures were made on two nights as follows:—

AB (NEW).

1903.026	59 .9	0″.26	7.5–7.5	1000,	3
.040	62 .9	0 .24	7.5–7.5	1500,	3
1903.03	61° .4	0″.25	7.5–7.5		

AB and C = Σ 1233.

1903.026	328° .8	18″.21	7.0–11.0	520,	3
.040	328 .9	18 .11	7.0–11.0	520,	3
1903.03	328° .8	18″.16	7.0–11.00		

STRUVE's measure of the wide pair is:—

1828.71	331° .5	18″.20	7.2–11.5

The star's approximate place for 1880.0 is R. A. 8^h $21^m.9$; Decl. — 2° 4′. R. G. AITKEN.

January 16, 1903.

PHOTOGRAPHIC OBSERVATIONS OF MINOR PLANETS.

Asteroids (415) *Palatia* and (439) *Ohio* were picked up by trails on negatives of forty minutes' exposure with the Crossley reflector on the night of June 23, 1902. On the same night Mr. PALMER and I secured four five-minute exposures on each asteroid. On the following night, Mr. PERRINE and I exposed two more plates on each object. Two exposures were made on each negative, the plate being moved in Right Ascension between successive exposures. In the reductions, the exposures on each plate were treated as so many comparisons in a micrometer observation, except in case of Plate 6, on which but one of the asteroid images was available for measurement. The measures have been corrected for refraction, scale value, and orientation. Mean places of the comparison-stars for 1902.0 were employed directly in the reduction, as precession and aberration simply affect the orientation.

The accompanying table contains the positions of the asteroids as determined from each plate and a comparison with ephemerides kindly furnished by Dr. E. F. CODDINGTON. The details of the measures will be published in the Lick Observatory *Bulletin*. In every case, the asteroid images were measured with some difficulty but more particularly was this true of the negatives of June 23d, when the seeing was poor.

R. H. CURTISS.

Plate.	Mt. Hamilton M.T.	α	δ	log *p* Δ		O − C		Exposure Time.
				α	δ	Δ α	Δ δ	
	(439) *Ohio.*							
	1902 h m s	h m s	° ′ ″			m s	′ ″	m
1	June 23 12 32 58	17 18 32.87	+0 34 0.8	9.211	0.722	+0 56 16	+2 10.1	5
2	23 12 46 55	17 18 32,44	+0 34 1.4	9.277	0 722	+0 56.15	+2 10 0	5
3	24 10 34 45	17 17 53.51	+0 34 58.9	n 8.826	0.728	+0 56 19	+2 9.8	5
4	24 10 47 45	17 17 53.08	+0 34 59.3	n 8 613	0 728	+0 56 16	+2 9.7	5
	(415) *Palatia.*							
5	June 23 10 56 55	15 33 51.63	−9 22 31.9	9.256	0 801	−0 35·25	+2 6.6	5
6	23 11 18 55	15 33 51.18	−9 22 32.6	9.346	0.798	−0 35.21	+2 6.6	5
7	24 9 32 45	15 33 23.00	−9 23 9.1	8.307	0 807	−0 35.11	+2 6.5	8
8	24 9 49 45	15 33 22.63	−9 23 9 7	8.437	0 807	−0 35.13	+2 6.4	8

THE COMETS OF THE YEAR 1902.

The year that has just closed will not be remembered as a remarkable one in the annals of cometary discovery, though PERRINE's comet (1902 *b*) proved to be the brightest one of recent years. Several periodic comets returned to the neighborhood of the Sun during the year, but all of them escaped detection, though they were searched for carefully, both visually and photographically. The four comets recorded were all unexpected ones, and two of them have added nothing to our knowledge of these bodies.

Comet *a*, discovered by Dr. BROOKS on April 14, 1902, was not announced until confirmed on the following night. Observations of it were secured at various stations in this country and in Europe on the nights of April 16th, 17th, 18th, and 19th; but, so far as I know, no one has seen it since then. Cloudy weather prevented observations here after April 16th, though the comet was seen for a few moments on the 17th. It was a morning object when discovered and was rapidly approaching the Sun, and its orbit was such that its apparent position in the heavens was very near that of the Sun for several months. After passing the Sun, the comet was looked for here in the positions predicted by the parabolic elements, and in those derived from LEUSCHNER's short-period ellipse, but it was not seen.

Comet *b*, discovered by PERRINE in the early morning of September 1, 1902, has been described at length in Nos. 86 and 87 of these *Publications*. The last observation secured here before the comet passed the Sun was made on November 17th. At present it is too far south to be observed from stations in the northern hemisphere, but it will again be in reach by the middle of February, and, if it is as bright as theory predicts, it should be for several months an easy object to observe.

It was announced in the *Astronomische Nachrichten*, and in the *Monthly Notices*, R. A. S., in September that Mr. JOHN GRIGG, of Thames, New Zealand, had discovered a faint comet on the 22d of July. Mr. GRIGG's letter states that he secured approximate measures of the comet's position on the nights of July 23d, 26th, 29th, and August 1st and 2d. Since then he has not seen it, and so far no evidence is at hand that it has been seen by any one else. Dr. KREUTZ communicated an ephemeris based on approximate elements computed by Mr. GRIGG, and the comet was looked for here on several nights without success. This object has been designated Comet *c* 1902.

The last comet of the year was discovered by M. GIACOBINI at Nice on December 2, 1902. The telegram announcing discovery reached us on December 4th, but clouds prevented observations until the following night. Since then measures have been made on a number of nights, the last being secured on January 7th. The comet is very small,—only 2′ or 3′ in diameter,—and quite faint, but possesses a well-defined nucleus of about the same brightness as a 13½-magnitude star. Its apparent motion is very slow, for it is still several months distant from perihelion, and only half a dozen known comets have a perihelion distance as great as that assigned to this one by the preliminary elements. For this reason it is not likely to be at all conspicuous, even when observed with a good telescope; but, from the situation of its apparent path through the sky, it is probable that its motion can be observed for a long time and data secured for an accurate orbit.

R. G. AITKEN.

Jan. 10, 1903.

THE SPECTRUM OF THE FAINT NEBULOSITY AROUND *NOVA PERSEI.*[*]

The anomalous changes which have been observed in the faint nebulosity surrounding *Nova Persei* made it highly desirable to obtain as great a variety of evidence as possible, particularly in the way of physical observations. In March, 1902, observations were secured with the Crossley reflector tending to show that there was little or no polarization in the light from the brightest of the condensations then visible.

The nebulosity was too faint to attempt any spectroscopic observations with the apparatus available. A slit-spectrograph having a quartz prism and quartz lenses was designed especially for this problem, to be used in connection with the Crossley reflector. The dispersion was purposely made very small.

A negative was secured on the nights of October 31st and November 1st, 2d, and 4th, with a total exposure of over 34 hours.

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[*] Abstract of L. O. *Bulletin*, No. —.

The slit of the spectrograph was placed across the brightest portion of Condensation D.

The resulting negative showed a very faint spectrum, which, after careful consideration and some experiments, was deemed to be that of the nebulosity. So far as can be told from such small dispersion and intensity, the spectrum is continuous, with the greater portion of the light condensed in a band between H_β and H_γ. This band is strongest just above H_β and from this point fades gradually until it is entirely lost in the H and K calcium region. Beyond this point, up in the ultra-violet region, there is a very slight increase of strength again.

It is suspected that in one or two cases there may be traces of bright lines, but the whole spectrum is so faint as to preclude any definite deduction on this point.

The above observation shows that the spectrum of this mass of nebulosity is not the ordinary bright-line spectrum of the nebulæ. The spectrum observed may correspond to that of the *Nova* at some epoch in its recent history, although that seems doubtful, from the fact that since July, 1901, (at least,) practically all the light of the *Nova* has been confined to a few lines. The faintness of the spectrum of the nebulosity makes it difficult to decide this point. C. D. PERRINE.

1903, January 13.

RED SUNSETS AT MT. HAMILTON.

Since the outburst of Mont Pelée in May last, the sunsets have been watched to see if there would be any such effects as were observed after the Krakatoa eruption of 1883. An augmentation of color was suspected in August and September, but as there was considerable smoke from forest fires in the lower atmosphere at that time, it was thought that that might be the cause. For several weeks past the atmosphere has been very transparent, owing to frequent rains and fogs, and favorable, therefore, for the detection of any unusual color due to dust in the upper atmosphere.

On many cloudless evenings a very perceptible deepening of color has been observed. The band near the horizon has been of a very deep crimson, and some color has usually been visible almost to the zenith. The tints are very clear and pure much more so that those usually resulting from smoke in the lower atmosphere. On several occasions the morning sky has shown some such effect, but much less marked than in the evening.

The recent sunsets are in no way comparable with the magnificent effects of 1883.

It is not possible to connect these appearances with certainty with the Martinique eruption or that in Guatemala. The surface currents in the atmosphere are contrary in both cases. Unless the matter was brought by reverse currents in the high atmosphere, it must have traveled almost around the globe. It is impossible, for reasons given above, to trace a relation by means of time. C. D. P.

1903, January 10.

GRANT FROM THE CARNEGIE INSTITUTION.

The Carnegie Institution has made a grant of $4,000 to the Lick Observatory for the present fiscal year of the Institution, to be expended in the employment of assistants and computers.

W. W. CAMPBELL.

ELEMENTS OF COMET *d* 1902.

From my observations of December 5 and December 30, 1902, and January 17, 1903, I have computed the following set of parabolic elements of Comet *d* 1902:—

$$\mathrm{T} = 1903,\ \text{March } 23.27958 \text{ G. M.T.}$$

$$\left.\begin{array}{rrrr} \omega = & 5^{\circ} & 45' & 4''.4 \\ \Omega = & 117 & 28 & 0\ .0 \\ i = & 43 & 53 & 57\ .9 \end{array}\right\} 1903.0$$

$$\log q = 0.443156$$

Residuals (O − C):—

$$\Delta\lambda' \cos\beta' = -3''.6\,;\quad \Delta\beta' = -3''.1$$

Constants for the Equator of 1903.0:—

$$\begin{array}{l} X = r\ [9.896716] \sin\ (221^{\circ}\ 33'\ 31''.7 + v) \\ Y = r\ [9.999990] \sin\ (131\ \ 15\ \ 44\ .4 + v) \\ Z = r\ [9.789065] \sin\ (\ 40\ \ 46\ \ 31\ .3 + v) \end{array}$$

R. G. AITKEN.

ASTRONOMICAL TELEGRAMS.

(Translations.)

CAMBRIDGE, Mass. Dec. 4, 1902.

To Lick Observatory: (Received 8:05 P.M.)

Kiel cables that a faint comet was discovered by GIACOBINI at Nice on December 2.396 G. M. T., approximately in the position R. A. $7^h\ 17^m\ 40^s$; Decl. — 1° 58′. Direction of motion, northwest. (Signed) E. C. PICKERING.

CAMBRIDGE, Mass. Dec. 4, 1902.

To Lick Observatory: (Received 8:35 P.M.)

Comet Giacobini was observed by DINWIDDIE at Washington on December 3.737 G. M. T., in R. A. $7^h\ 17^m\ 24^s$; Decl. — 1° 50′. The position is approximate.

(Signed) JOHN RITCHIE, JR.

MT. HAMILTON, CAL., Dec. 6, 1902.

To Harvard College Observatory: (Sent 9:55 A.M.)
To Students' Observatory, Berkeley, Cal.:

Comet Giacobini was observed by AITKEN on December 5.9848 G. M. T., in R. A. $7^h\ 16^m\ 45^s.7$; Decl. — 1° 31′ 2″.
(Signed) R. H. TUCKER, in charge.

MT. HAMILTON, CAL., Dec. 8, 1902.

To Harvard College Observatory: (Sent 9:45 A.M.)
To Students' Observatory, Berkeley, Cal.:

Comet Giacobini was observed by AITKEN on December 6.7930 G. M. T. in R. A. $7^h\ 16^m\ 30^s.7$; Decl. — 1° 23′ 49″; and on December 7.8192 G. M. T., in R. A. $7^h\ 16^m\ 9^s.8$; Decl. — 1° 14′ 30″. (Signed) R. H. TUCKER, in charge.

BOSTON, MASS., Dec. 15, 1902.

Elements and ephemeris of Comet Giacobini were computed at Washington as follows:—

$$
\begin{array}{rl}
T = & 1903,\ \text{April } 1.7863,\ \text{G. M. T.} \\
\left.\begin{array}{r} \omega = \\ \Omega = \\ i = \end{array}
\begin{array}{rrr} 9^\circ & 47' & 7'' \\ 117 & 12 & 35 \\ 43 & 53 & 29 \end{array}\right\} & \text{Mean equator of } 1902.0 \\
\text{Natural } q = & 2.686
\end{array}
$$

(Signed) JOHN RITCHIE, JR.

[The ephemeris at 4-day intervals to December 29 is here omitted.]

NEW
UBLIC LIB.
ASTOR, LENOX AND
TILDEN FOUNDATIONS.

REPORTS OF OBSERVATORIES.

The annual publication in one place of brief reports upon astronomical researches made in this country would seem to be desirable. Those desiring to prepare such reports are requested to forward manuscript to **Frank Schlesinger**, International Latitude Observatory, Ukiah, California.

NAVAL OBSERVATORY, WASHINGTON, D. C.

During the year the following changes have taken place in the personnel:—

Professors of Mathematics Thos. J. J. See and Milton Updegraff were detached from the Observatory on September 20, 1902, and ordered to duty as instructors in the Department of Mathematics at the United States Naval Academy, where their services were urgently required, owing to the great scarcity of line officers in the navy who had formerly done this work.

November 1, 1902, Captain Chas. H. Davis, U. S. N., was relieved as Superintendent by Captain Colby M. Chester, U. S. N.

The instruments have been used as follows:—

The 6-inch transit-circle has been devoted to routine observations of the Sun, Moon, and planets, together with the special lists of heliometer comparison-stars issued by Sir David Gill.

The 9-inch transit-circle has been undergoing repairs and improvements.

The prime vertical transit instrument has been devoted to observations for the determination of aberration, nutation, and variation of latitude, and to the determination of the Declinations of 390 miscellaneous stars.

The alt-azimuth instrument has been devoted to a determination of the latitude of the Observatory and the Declinations of 350 standard stars.

Photographs of the Sun have been obtained with the photoheliograph on every clear day.

The equatorials have been devoted to measurements of the diameters of the planets, to observations of their satellites, to observations of asteroids, comets, occultations, and variable stars.

During the year volume II, Publications of the U. S. Naval Observatory, Second Series, containing the observations of the

Astronomische Gesellschaft Zone — 13° 50′ to — 18° 10′ has been issued, and volume III is in press.

The formation of the catalogue from the observations in volume II is in progress, and some work has been done on cataloguing the Washington Zones 1846 to 1852.

A very important part of the work of the Observatory consists in the inspection, purchase, care, and issue of chronometers, watches, sextants, octants, telescopes, binoculars, and surveying and photographic outfits, including all nautical instruments except compasses. The regular annual trial of chronometers includes about one hundred chronometers, of a value of about $30,000, and lasts six months. The time service, maintained in connection with the chronometer service, sends out daily, except Sundays and holidays, telegraphic noon-signals that reach all points of the country, correcting some 40,000 clocks and dropping sixteen time-balls.

The following articles from members of the Observatory staff have appeared during the year: The Naval Observatory Eclipse Expedition to Sumatra, by A. N. Skinner, (*Popular Astronomy,* January, 1902); Observations of the Diameters of the Satellites of *Jupiter* and of *Titan,* the Principal Satellite of *Saturn* (observations by daylight), by T. J. J. See, (*A. N.,* No. 3764); Micrometrical Measures of the Equatorial Diameter of *Saturn* and of his System of Rings (observations by daylight), by T. J. J. See, (*A. N.,* No. 3768); Micrometrical Measures of the Diameter of *Uranus* (observations by daylight), by T. J. J. See, (*A. N.,* No. 3768); Observations of the Satellites of *Saturn* and *Uranus,* by T. J. J. See, (*A. N.,* No. 3806); Observations of Heliometer Comparison-Stars, by M. Updegraff and J. C. Hammond, (*A. J.,* No. 528); Micrometric Measures of Double Stars, by E. A. Boeger, (*A. J.,* No. 522); Observations of (26) *Proserpina,* by G. K. Lawton, (*A. N.,* No: 3786); Some Results of the Total Eclipse in Sumatra, of May 18, 1901, obtained with the Photoheliograph, at Fort de Kock, by G. H. Peters, (*Astrophysical Journal,* September, 1902); Elements and Ephemeris of Comet 1902 *d,* by H. R. Morgan and C. W. Frederick, (*A. J.,* No. 528); A Device for Conducting Electric Circuits to the Eye-end of the Equatorial Telescope, by W. W. Dinwiddie, (*Popular Astronomy,* June, 1902); Observations of Comet 1902 *d,* by W. W. Dinwiddie and C. W. FREDERICK, (*A. J.*, No. 528); Observations of Comet 1902 *d*, by W. W. DINWIDDIE, (*A. J.*, No. 528).

C. M. CHESTER, *Captain, U. S. N.,*
Superintendent Naval Observatory.

January 12, 1903

OBSERVATORY OF THE UNIVERSITY OF MINNESOTA.

The research work of the Observatory has been confined almost exclusively to measurement and reduction of the series of *Eros* photographs made during the winter of 1900. In taking these photographs the plan followed was to make all the exposures of a single night on the same plate; so when one plate is worked up the work of that night is finished. Exposures were made at as great hour-angles as possible, so that the Sun's parallax might be obtained by the morning and evening method. This plan was successfully carried through on about fifteen nights, and only partially so on some thirty-five nights.

Twenty-one of the most perfect plates have been measured. They contain on an average about twelve exposures and thirteen reduction-stars. A number of filar micrometer comparison-stars were also measured, that their positions might be accurately determined. Many of the stars, however, were too faint to be photographed. Three of the plates have been provisionally reduced and the Sun's parallax computed.

From these the probable error of the position of an image, in one equation of condition, is about one tenth of a second. The probable error of the Sun's parallax, of course, will depend on the hour-angles at which the exposures were taken and the resulting parallax factor. In one of the above cases the factor is 20, making the probable error of the Sun's parallax from the night's work about 0″.02.

Some difficulty has been experienced in making the measurements on account of bad images near the edge of the plates. They are usually round and well defined near the center. But half-way out from the center they begin to develop comet-like tails. These tails I afterward found may be almost completely eliminated by capping the object-glass down from its full aperture 10½ inches to 9 inches. This is accomplished also without materially weakening the intensity of the images.

The results of the preliminary reductions lead me to believe that the final reduction of the whole series of photographs will be reasonably accurate.

January 1, 1903. F. P. LEAVENWORTH.

VASSAR COLLEGE OBSERVATORY.

PROFESSOR MARY W. WHITNEY, DIRECTOR.

1. Publications of Vassar College Observatory during 1902: Observations of *Nova Persei*, by MARY W. WHITNEY and CAROLINE E. FURNESS (*Ast. Nach.*, 3757); Observations of Minor Planets, by MARY W. WHITNEY and CAROLINE E. FURNESS (*Ast. Jour.*, 517); Ditto, ditto (*Ast. Nach.*, 3795); Observations of Comet *b*, 1902, (PERRINE), by MARY W. WHITNEY and CAROLINE E. FURNESS (*Ast. Jour.*, 528); Prediction of maxima and minima of variable stars of long period for 1902, by IDA WATSON and HELEN SWARTZ, graduate students in Astronomy (published monthly in *Pop. Ast.* for 1902); the variable star *U Cephei*, by IDA WATSON (*Pop. Ast.*, June, 1902).

2. Observations of minor planets and comets are being made continuously though somewhat irregularly. There are now on hand, in various stages of reduction, about thirty observations of *Eros* and the same number of observations of minor planets.

3. During the past year, Miss COWLEY, a graduate student, was engaged in computing the definitive orbit of Comet 1826 II. A portion of the work—viz., the determination of the Right Ascensions and Declinations and proper motions of the comparison-stars—has already been completed, and was accepted as a thesis for the A. M. degree at Vassar College.

The most important work carried on is the measurement and reduction of photographic plates, a continuation of the work included in *Publications* I of the Observatory. Of the eight plates covering the region 88° to 89°, six have been measured and partially reduced. For the remaining measurement and the completion of the reduction the Observatory has received from the Carnegie Institution a grant of $1,000, to enable us to finish the work in a year's time. The money will be expended in employing additional computers, since a large portion of the time of the director and the assistant is given to instruction.

POUGHKEEPSIE, January 6, 1903.

ASTRONOMICAL OPERATIONS OF THE U. S. COAST AND GEODETIC SURVEY.

In the main portion of the United States the only astronomical observations were at Tonopah, Nevada, the latitude and longitude being determined, and at Iron Mountain Furnace Tract, Tenn., latitude only. In Alaska the latitude and longitude of a point on St. Lawrence Island and of a point on Nunivak Island were determined, the longitudes being observed by the chronometric method. No astronomical observations were made in Hawaii or in Porto Rico.

In the Philippines the latitudes of twenty-nine stations have been determined. The longitudes of twenty-eight stations have also been determined with reference to Manila, of which the longitude had previously been determined through the cable; and azimuths were observed at twenty-three stations. Of the twenty-eight longitudes in the Philippines, twenty-seven were determined by the telegraphic method and one by the chronometric method. The figures given above for the Philippines include all stations from which any reports have reached the Washington Office up to this date, and include observations in both 1901 and 1902.

F. W. PERKINS, *Acting Superintendent.*

January 9, 1903.

HARVARD COLLEGE OBSERVATORY.*

East Equatorial.—The observations with this instrument have been made by Professor O. C. WENDELL, and have been of the same general character as in previous years. Seventeen thousand photometric light comparisons have been made, principally with the polarizing photometer with achromatic prisms. With this photometer 1,024 comparisons were made of *X Cancri*, 992 of *U Cephei*, 960 of *U Sagittæ*, 944 of *U Scuti*, 880 of 78.1901 *Cygni*, 800 of *R Ursæ Minoris*, 752 of *β Persei*, 736 of *χ Cygni*, 528 of *β Lyræ*, 480 of *W Delphini*, 448 of *U Ophiuchi*, 416 of + 43° 4101, recently discovered here, 384 of *Nova Persei*, No. 2, 320 of *X Persei*, 192 of *R R Lyræ*, 160 of *S W Cygni,* 160 of standard stars in the cluster *Messier* 15, 144 of *Y Cygni,* 96 of *R Coronæ,* 96 of *SS Cygni,* 64 of *T Cygni,* 64 of *T Persei,* 64 of *μ Herculis,* 48 of *R Lyræ,* and 32 each of *U Geminorum, X Herculis,* d *Serpentis, μ Cephei,* and *X Virginis.* In addition to the above, 1,984 comparisons were made of o *Ceti,* 288 of *U Camelopardalis,* and 1,968 of double stars, with a second photometer adapted to the comparison of stars too near together to be measured with the first instrument. The same instrument has been used in the photometric measurement of *Jupiter's* satellites while undergoing eclipse. Seventeen eclipses have been observed, making the total number 736, Photometric observations of comparison-stars for variables have also been continued, the number of settings being 192. The systematic observation of variable stars of long period throughout their changes, and the reduction of the results to the scale of the meridian photometer have been continued. Two hundred and fifty estimates by the method of Argelander have been made, generally when the stars were too faint to be observed with small instruments. The selection of fourteenth magnitude standards has been continued. Several other objects of a miscellaneous character have also been observed.

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* Extracted, with Professor PICKERING'S permission, from the *Fifty-seventh Annual Report of the Director of the Astronomical Observatory of Harvard College for the year ending September 30, 1902.*

Similar observations of variables and comparison-stars have been made with the West equatorial. With it 1,130 estimates of variables, and 235 estimates of comparison-stars have been made by Miss Cannon, 3,324 estimates of variables, and 170 estimates of comparison-stars have been made by Mr. Campbell, with the naked eye, field-glass, and a 5-inch portable telescope. Three hundred and ninety-one estimates of variables have been made by Mr. Colson, and 326 by Mr. White. Nine hundred and eighty-one estimates of variables have been made by Mr. F. E. Seagrave, of Providence, and communicated by him to this Observatory. Observations of variable stars have also been communicated by six other persons.

Meridian-Circle.—The principal use of this instrument during the year has been the determination of clock error, but on 20 dates observations of *Nova Persei,* No. 2, or faint stars in its vicinity, were made by Mr. Dunne. The total number of transits, including those of circumpolar and almanac stars required for the reduction of the observations was 218. On 10 other dates observations were made with wire screens, in order to furnish an independent determination of personal equation with respect to magnitude. These observations have not yet been reduced. The power of the instrument in exhibiting faint stars was compared with that of the four-inch transit-circle of the Students' Astronomical Laboratory, by a short series of observations in June, 1902, from which it appeared, as had been previously thought, that the 8-inch object-glass of the meridian circle was less efficient than would be supposed from its size.

The reduction of the observations of stars in the zone — 9° 50′ to — 14° 10′ has proceeded so far that the results in Right Ascension and Declination for 1900.0 are now very nearly complete, and are collected in readiness for the computation of the mean result for each star. But it is expected that cases of large discrepancy, especially in the observations of the years 1896 to 1898, will be found to require a second reduction, and that entire zones may need small corrections when the residuals of the separate observations have been obtained for the zone journal. The work of collecting the estimates of magnitude is also largely completed, and the preparation for publication, both of the final catalogue and of the zone journal, has been begun.

The reduction of the observations made by the late Professor ROGERS, during the years 1879 to 1883, has been continued by Miss S. C. BOND under the supervision of Miss ANNA WINLOCK. The computation of the reductions from apparent to mean place at intervals of ten days for all the stars observed is now complete. About 3,000 reductions for single observations have been obtained by interpolation from these computations, and about as many more remain to be obtained.

12-inch Meridian Photometer.—With this instrument 66,932 settings have been made by the Director on 118 nights. In all, 265,604 settings have been made in four years. The principal work has been the extension of the photometric scale from the tenth to the thirteenth magnitude. Sequences of stars have been selected and measured for all the regions contained in Series I, II, and III, of HAGEN's Catalogues, from the magnitude 7.5 to 12.5, and in Series IV, from 7.5 to 10.5.

Meridian Photometer.—With this instrument 10,784 measures were made by Professor BAILEY on 30 nights, from

October 1, 1901, to April 18, 1902. It was then dismounted and sent to Peru, where he obtained 7,804 settings on 18 nights, from July 10 to September 30, 1902. The principal objects observed were a series of stars of about the fifth magnitude, one in every region 10° square. Each star was to be observed twice on ten nights, taking various precautions so that the resulting magnitudes should furnish accurate standards of photometric magnitude, from the north to the south pole. Various miscellaneous objects, including comparison-stars for *Eros, Iapetus,* and variables, were also measured. The total number of settings so far obtained with this instrument is 1,051,768.

Henry Draper Memorial.—Since its establishment in 1886, the Henry Draper Memorial has developed three new and unique lines of work. *First,* by the substitution of the objective prism and doublet for the slit spectroscope and single lens, the spectra of large numbers of stars are photographed simultaneously by the former, instead of singly by the latter method. These photographs have been repeated until every portion of the sky has been covered, using the 8-inch Draper telescope for the northern stars, and the Bache telescope, an 8-inch doublet of similar construction, for the southern stars. As a result, we have a photograph of the spectrum of every star in the sky permanently brighter than the ninth or tenth magnitude, besides many thousands that are fainter. These plates have been carefully examined by Mrs. FLEMING, with the result that large numbers of objects having peculiar spectra have been discovered. The number of such objects found elsewhere is small, and it is probable that all that are bright have been found from these plates, thus making this part of the work complete. We are now extending it to the fainter stars, using smaller dispersions and longer exposures. There are two classes of stars that can only be studied by frequent photographs like those described above. Of the eight *Novæ* which are known to have appeared during the last sixteen years, two were bright and visible to the naked eye. All of the others were found from the Draper photographs, and would probably otherwise never have been discovered. Variable stars of long period have very peculiar spectra, which differ greatly from one another, and can generally be photographed only when they are bright. Nearly two hundred of these objects have been discovered from the Draper photographs. *Secondly,* by placing large objective prisms in front of the 11-inch Draper telescope, stellar spectra six inches long and showing several hundred lines have been obtained. Shorter spectra were obtained of the fainter stars, and from them a detailed study of 681 of the brighter stars visible in Cambridge was made by Miss MAURY. A similar study of 1,122 southern stars photographed with the 13-inch Boyden telescope has been made by Miss CANNON. Although the stars have thus been arranged in a logical sequence, the object was rather to show that large numbers of stars had identical spectra, and then to publish all the facts regarding a typical star of each group. All the material is thus furnished to any future investigator, so that he may continue his studies without having recourse to these or other photographs. The discovery of spectroscopic binaries, of stars having the hydrogen lines bright and variable, and of a new series of hydrogen lines, resulted from these investigations. The third field of work is perhaps the most important of all. By photographing repeatedly all portions of the northern sky with the 8-inch Draper telescope, and of the southern sky with the Bache telescope, we have a map of the entire sky showing all the brighter stars night after night. This furnishes a complete history of the heavens for every year since 1890, and a partial history since 1886. When any new object is discovered, we can trace its motion or variations in brightness, throughout this period from these photographs. As no such collection of photographs has been made elsewhere, the importance of properly caring for it, and continuing it, is obvious. An additional force of assistants is much needed to study these plates, and thus determine the past history of known objects, and of new ones as fast as they are discovered.

The number of photographs taken with the 11-inch Draper telescope is 475, making 14,020 in all with this instrument; with the 8-inch Draper telescope, 1,642, making in all 29,298. The total number of photographs of the stars taken at Cambridge during the year is 4,254. Fifteen eclipses of *Jupiter's* satellites, and ten occultations, have been successfully photographed with the 11-inch Draper telescope. Four variable stars have been found by Mrs. FLEMING from an examination of the Draper photographs. One of these, + 43° 4101, proved to be an *Algol* variable with a period of 30 days, and duration of obscuration 2 days. This period is much longer than that of any other *Algol* star as yet discovered, the next longest period being that of *S Cancri,* which is 9.5 days. The other three were found from the presence of bright hydrogen lines in their spectra. One of these, whose position for 1900 is R. A. = $12^h\ 50^m.7$, Dec. = —57° 21′, has a peculiar spectrum. A fifth variable, + 40° 4390, found by Mr. J. A. DUNNE with the meridian-circle, was confirmed by the Draper photographs.

The general plan of taking the photographs, as described in the last report, has been maintained under the direction of Mr. KING. The illumination of the sky by electric lights limits the time of exposure, as the faintest stars do not appear when the fogging of the plates exceeds a small amount. For this reason, an exposure of three hours with the 8-inch Draper telescope fails to show faint stars any better than an exposure of one hour; and this instrument is not used, even for exposures of ten minutes, for several days each month, on account of the Moon. Several of the brighter asteroids are photographed every month as standards of magnitude in different parts of the sky.

Boyden Department.—The station at Arequipa remained under the charge of Mr. H. C. BAILEY from October 1, 1901, to March 1, 1902. It was in charge of Mr. R. H. FROST from March 1 to June 1, 1902, and since June 1, 1902, in charge of Professor BAILEY. The number of photographs taken with the 13-inch Boyden telescope is 276, making 10,630 in all. A few of these are charts of clusters, but nearly all of the remainder are photographs of the spectra of stars in which the hydrogen lines appear to be variable, and of spectroscopic binaries. Two thousand one hundred and forty plates have been taken with the Bache telescope, making 30,748 in all. Nearly all of them are charts with exposures of 10^m and 60^m. The total number of photographs taken at Arequipa during the year is 3,919. One reason for Professor BAILEY's trip to Peru was to study the variations in light of the planet *Eros.* At its next opposition, this planet is so far south that it cannot readily be observed in Europe or in the United States, and is so faint that powerful instruments will be required to observe it. The meridian photometer has accordingly been sent to Peru to determine standards for comparison, and also to continue the work undertaken here, as described above. One of the photometers used in the determination of faint stellar magnitudes by the co-operation of the Yerkes, Lick, McCormick, and Harvard Observatories, has also been sent to Peru. This photometer has been attached to the 13-inch Boyden telescope, and has already been used by Mr. BAILEY on 24 nights, from July 28 to September 30, 1902. Measurements have been made with it of *Sirona, Tercidina,* of camparison-stars for variables, and of a few variables. Attempts have been made to secure monthly observations, by ARGELANDER'S method, of 50 southern variables. This has been much interrupted by other work, but since March, 1902, it has been actively resumed.

Bruce Photographic Telescope.—During the last year, 438 plates have been taken with the Bruce photographic telescope, making 6,174 in all. Before February 1, 1902, these plates were taken by Dr. DELISLE STEWART, and since then by Mr. R. H. FROST. With this instrument, excellent chart plates can be obtained of regions 5° square, the images in the centers of the plates being almost perfectly circular even when the exposure lasts four or five hours. A large number of trails of asteroids have been photographed, several of which are probably new. One of these has a greater eccentricity than any other known asteroid, and exceeds that of some of the periodic comets. The name *Ocllo* has been given to it by the discoverer, Dr. STEWART, after the Peruvian goddess, who with her brother Manco was supposed by the Incas to have descended from the Sun. A photograph of *Eros* was obtained on July 7, 1902, nearly a month before it was observed elsewhere after its conjunction with the Sun.

Blue Hill Meteorological Observatory.—The work of the Observatory was performed, under the direction and at the expense of Mr. ROTCH, by the three assistants formerly employed. The special investigations in 1902 included determinations by day and night of the atmospheric refraction above land and water, and a few measurements of the quantity of carbon dioxide in the air and of the electrical potential of the air, by Mr. G. W. PICKARD. Commencing in December, kite-flights were made on a fixed day each month, in co-operation with simultaneous ascensions of balloons and kites in Europe. The mean altitude above the sea of the meteorograph in the ten flights at Blue Hill was 9,200 feet, which is 1,925 feet above the mean of the flights during the preceding year, and is the highest annual average yet attained. The maximum altitude of 14,060 feet exceeds by 1,510 feet the highest flight of the year before. Mr. ROTCH'S project of exploring the atmosphere above the tropics and the Equator with kites flown from a steamship was approved by the International Aeronautical Congress that met at Berlin in May, and he has requested a grant from the Carnegie Institution to partially defray the cost of the expedition. The Observatory is being remodeled, and a much needed fireproof building for the library and records generously added by Mr. ROTCH, at an approximate cost of $6,000.

Library.—The library of the Observatory has been increased by 292 volumes and 973 pamphlets. The total numbers of volumes and pamphlets in the library on October 1, 1902, were 10,369 and 17,179, respectively. Special efforts are being made to render the meteorological, as well as the astronomical, collection of publications here and at Arequipa as complete as possible. Owing to the number of buildings connected with the Observatory, duplicates of important publications are in constant use. Every year the need of additional space for books is becoming more urgent.

Telegraphic Announcements.—Of the 22 messages distributed this year, 4 were received from Professor KREUTZ, Kiel, 9 from the Lick Observatory, 3 from the Yerkes Observatory, 2 from Professor BROOKS, and one each from four other sources. The distribution of the announcements by telegraph is continued to such subscribers as wish to pay for the messages.

Time Service.—On June 14, 1902, a new system of public time signals, devised by Mr. GERRISH, was put into operation. Incandescent electric lights are made to pulsate in response to the telegraphic signals of the standard clock, reproducing visually the regular standard signals which have hitherto been sent out by telegraph.

Publications.—Volumes XXXVI, part II, XXXVIII, XLI, Nos. VII, VIII, and IX, XLIII, part II, and XLVIII, No. I, have been printed and distributed. Volume XLIV, part II, Reduction of Observations made with the Meridian Photometer during the years 1892 to 1898, is in type. Fifty-five pages of volume XLVI, Observations of Southern Stars, made with the Meridian Photometer in 1899, 17 pages of volume XLVII, Observations of Photographic Variables, pages 39 to 83 of volume XLVIII, Observations of the Light Curve of *Nova Persei*, No. 2, and 14 pages of volume XLIX, Photometric Observations made with the East equatorial, are in type.

The first forty-five volumes of the Annals are therefore completed, with the exception of volumes XXXIX, XLIII, and XLIV, of which the first portions only have been distributed. The four volumes following XLV have also been begun. Four circulars have been issued during the year: 62. Spectrum of Lightning (November 16, 1901); 63. An Asteroid Orbit of Great Eccentricity (November 19, 1901); 64. Early Observations of *Algol* Stars (January 18, 1902); 65. A New *Algol* Variable (May 6, 1902).

The building containing the collection of photographs of the sky had become so crowded that no room was available for the additional photographs which are made on every clear night, and yet the value of the collection is increasing every year, and furnishes the only existing history of the stellar universe for a definite number of successive years. A friend has presented the Observatory with $20,000, making no condition except that the name of the donor should not be mentioned. A portion of this gift has enabled the Director to add to the building containing these photographs a fireproof wing of plain brick; it will provide for the growth of the collection during the next ten or fifteen years. Again, recent experiments have proved that a large reflector will show stars so faint that their study with other telescopes is impossible. We have contracted with the firm of ALVAN CLARK & SONS for a mirror two feet in diameter, to be used first on the northern and then on the southern stars, thus extending our work to vast multitudes of stars hitherto beyond our reach. The mounting will be constructed in our own workshop with a great saving of expense. It is hoped that results will be such as to influence others by the example of this gift, so that the other departments of the Observatory may be made to correspond to its great development in certain directions. The library of the Observatory, one of the most complete and valuable in the world, is in a wooden building half a century old and is liable to destruction by fire at any time.

The building containing the photographic laboratory and machine shop is also of wood and wholly inadequate for these purposes.

Another anonymous gift has been received, which is of interest as suggesting a much wider field of usefulness for the Observatory than it now occupies. This gift at present amounts to $70,000, of which $10,000 is at once available. The income may be used for any astronomical work, whether undertaken at the Harvard Observatory or elsewhere. The first appropriation was made last summer to furnish an assistant at another observatory, so that one of the largest telescopes in the world could be used during hours at which it would otherwise be idle. The Director of the Harvard Observatory is always likely to know of ways in which money could be expended to especial advantage for astronomical research. A pamphlet was published in 1886 by the undersigned, recommending the establishment of such a fund, and in 1890 Miss C. W. Bruce gave $6,000, which was expended in this way. It is believed that the results attained show how advantageously such a fund can be administered here. The usefulness of this Observatory would be greatly increased if it should become an important part of the duty of its Director to aid other observatories and astronomers, to secure observations in neglected departments of astronomy, and to enable competent observers to use the numerous large and valuable telescopes now idle. It seems as if the moral effect of thus bringing together the astronomers of the world so that they might work harmoniously on researches too large to be undertaken by any one of them, must appeal to some of the many friends and patrons that astronomy has always had. The pamphlet mentioned above contains the reasons for believing that great permanency of good management, and efficiency in the expenditure of such a fund could be attained here. At least, the present condition of the Observatory is such as to insure the immediate expenditure of several thousand dollars a year to great advantage in this way.

Edward C. Pickering, *Director*.

THE CINCINNATI OBSERVATORY.

As the staff of the observatory consists of but two,—the director and one assistant,—as considerable teaching is required, the scientific work that can be accomplished is quite limited.

Observations for the variation of latitude, undertaken in connection with the International Geodetic Association, have been prosecuted during the year 1902 as usual. For this work the zenith telescope loaned by the U. S. Coast and Geodetic Survey has been employed. This instrument is by Wanschaff, and is similar in construction to those of the four main stations, but somewhat smaller. The number of pairs of stars secured is as follows:—

January . . .	116	July.	166
February . .	86	August . . .	165
March	130	September . .	15
April	118	October . . .	155
May.	154	November . .	136
June	122	December . .	72
		Total .	1,435

The meridian-circle has been employed in the redetermination of the stars of Piazzi's catalogue north of the equator. About 3,000 observations were secured, and this scheme of work is now nearly completed.

The weather during the year has been much more unfavorable than in 1901. J. G. Porter, *Director.*

INTERNATIONAL LATITUDE STATION, UKIAH, CALIFORNIA.

The programme of the International Geodetic Association for observing variations of latitude was continued throughout 1902 without modification or interruption. The number of pairs observed in each month is given below:—

1902, January . . .	150 pairs	1902, July.	207 pairs
February . .	37	August . . .	215
March	188	September . .	180
April	167	October . . .	194
May.	173	November . .	157
June	199	December. .	155

The total number is 2,022. The conditions that prevailed in February are not likely to be repeated here soon; during this month 19.4 inches of rain fell, more than during any other month since 1877, when the meteorological records for this place were begun.

Besides these observations for latitude proper, auxiliary observations were made for determinations of the instrument's position and adjustment, of the micrometer value, of the values of the level spaces, and of the periodic errors of the micrometer-screw.

FRANK SCHLESINGER.

2 Jan., 1903.

GENERAL NOTES.

By **FRANK SCHLESINGER.**

The Constant of Aberration and the Solar Parallax.—Recent series of observations, and the recomputation of earlier ones when the variation of latitude is taken into account, indicate that the value hitherto assigned to the constant of aberration is too small by about 0″.05. It is only a few years since the heads of four national observatories and several other prominent astronomers met at Paris to recommend a series of constants for uniform use in the ephemerides. The value of the aberration there adopted was 20″.47, replacing STRUVE'S classic value of 20″.445; but now it seems nearly certain that the true value is above 20″.50, and probably 20″.52 would be the nearest estimate which our present knowledge permits us to make.*

So far as the requirements of the ephemerides are concerned, this modification of the value of the aberration would not be of great consequence; at most it corresponds to a change of a few hundredths of a second of arc in the "reduction to apparent place" of the stars. But when we consider the aberration in connection with the solar parallax, for example, a change of 0″.05 is a most important one. These two quantities (usually denoted by k and π respectively) are related to V, the velocity of light *in vacuo,* by the simple equation,

$$k \times \pi \times V = \text{a constant}$$

This constant is known with great precision, its probable error not exceeding one part in twenty thousand. The velocity of light is also known quite accurately,—compared with our knowledge of k and of π,—its probable error not being greater than one part in two thousand. If we replace the constant and V in the above equation by their standard values, we get a relation between k and π. The table below shows what values of the solar parallax would follow from various values of the aberration when we use this relation:—

20″.445	(STRUVE'S value)	8″.813
20 .47	(Paris Conference)	8 .802
20 .52		8 .781

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* In *Astronomical Journal* No. 529, which has come to hand since this note was written, Dr. CHANDLER expresses the conviction that the "real value of this much disputed constant is likely to be found near or slightly above 20″.52."

Thus we see that the new value of the aberration implies a solar parallax about 0″.02 smaller than the usually accepted value of 8″.80. The latter is the result of so much labor and ingenuity that we should hardly expect it to be in error by so much, and it is therefore difficult to reconcile the results of observations on these two constants. Perhaps the completion of the *Eros* work and the more accurate knowledge of latitude variations that is now being accumulated may cause this difficulty to disappear.

In this connection there is another consideration which should be mentioned, though it is rather of philosophical than of practical interest. The equation which we have used to connect the aberration with the solar parallax and the velocity of light has never been rigorously demonstrated. It is equivalent to the explanation advanced by BRADLEY when he discovered the aberration nearly two centuries ago (1729). Now, in BRADLEY'S time the corpuscular theory of light, resting on the great authority of NEWTON, was universally accepted; and if this theory were the true one, BRADLEY'S explanation, and therefore our equation, would be rigorously demonstrated. We know now that light is a series of undulations in the ether, and that BRADLEY'S explanation is no longer satisfactory. The difficulty arises from the unknown effect of the relative motion of Earth and ether. The reader is referred to the article on "Ether" by J. CLERK MAXWELL in the *Encyclopædia Britannica* (Ninth Edition, Vol. VIII, pp. 503 et seq.), and to Mr. SEABROKE'S presidential address, printed in the Journal of the British Astronomical Association (Vol. XII, No. 1). This problem demands the use of the most refined mathematical analysis. It has been attacked by some strong men, but a complete solution is still wanting, and some unpalatable assumptions have been made with regard to the nature of the ether. While we need hardly fear a modification of our equation to a degree which present methods of observation could appreciate, it would certainly be a great satisfaction to know just how close an approximation it is and to have a complete theory of aberration.

The Difficulty of Determining the Constant of Aberration.—The two constants that we have been discussing happen to be among the most difficult to determine among all those with which astronomy has to do. That this is true of the solar parallax is well known and understood, but the difficulty of determining the constant of aberration seems not to be so generally recognized. In considering the accuracy attainable for various astronomical phenomena, an obvious distinction presents itself between such as are *accumulative* in their character and those that are *periodic* or *stationary*. The former have a faculty of taking care of themselves, so to speak, with the lapse of time. For example, we can determine the annual precession of the equinoxes with any required degree of accuracy from two series of observations of the Sun and the stars, no matter how rough these may be, providing only that the interval of time between the two series be great enough. From a comparison of the observations of HIPPARCHUS and of TYCHO BRAHE we can get the annual precession with greater accuracy than attaches at present to many of the constants of astronomy. In this class with precession belong the proper motions of the stars, the rotation periods of the Sun and the planets, the periods of revolution (and therefore the relative distances) of planets around the Sun and of satellites around planets, the periods of variable and binary stars, and indeed all the periods in astronomy.

The other class of phenomena, those which receive no such powerful aid from time, are not susceptible of so great accuracy. These must depend upon the mere accumulation of observations or upon improvements in instruments and methods. The number of astronomical phenomena here included is practically without limit, but among them we may distinguish as especially difficult of determination those that have an annual period; the absolute parallax of a fixed star and the aberration are examples. Either of these depends essentially upon the accurate observation of the place of a star at two opposite seasons of the year. Now, it would be desirable that these observations should be made under nearly uniform conditions, but it is easy to see that changes of season make this impossible. Let us suppose, for example, that the apparent place of the star varies slightly with temperature; then our summer results will differ systematically from those of the winter, and error will creep into our determination of parallax or aberration. It is true that the effects of temperature are understood and may be approximately allowed for, but there are other effects that come with the changes of season which have not been reduced to law, or, worst of all, whose very existence is not suspected. No better example in this connection could be cited than Airy's experience with the *reflex zenith-tube* at Greenwich. A long and careful series of observations upon a certain star with this instrument yielded a value for the aberration which is certainly too small by nearly 0".2. It was not until long after the instrument had been all but abandoned that the mystery was explained away by Chandler; the latitude variation (a phenomenon unsuspected by Airy or any of his contemporaries) has, among others, an annual term. These others are eliminated, so far as the aberration is concerned, in a series of observations extending over many years. But as the annual term did not vary to any great extent in this period, its effects were practically repeated from year to year, and were closely interwoven with those of the aberration itself, the periods of the two being identical. The annual term in the latitude variations certainly has its cause in the changes of season, and we may be sure that similar effects, though perhaps none so great, lie hidden in observations of our day and of the past, to be unearthed by astronomers of the future.

Comet Notes.—Four comets were discovered in 1902—

a by Brooks,	Geneva, N. Y ,	on	April 14.
b by Perrine,	Lick Observatory,	on	August 31.
c by Grigg,	New Zealand,	on	July 23.
d by Giacobini,	Nice,	on	December 2

Comet *b* (Perrine) was for several weeks an easy naked-eye object, having attained at one time the brightness of a fourth-magnitude star. This comet is also interesting on account of its close approach to *Mercury* on November 30th, which may lead to a valuable determination of the planet's mass from its effect upon the comet's orbit. Luckily this comet has a well-defined nucleus, so that accurate measures of its position are possible.

Comet *c*, not an excessively faint object and well located for observations in both hemispheres, was nevertheless seen only by its discoverer, Mr. John Grigg, of Thames, New

Zealand. Mr. Grigg lacked the means for any but very rough measurements of the comet's position; so that the seemingly impossible thing has happened, in this day of many telescopes and of telegraph and cable, that we know practically nothing of the orbit of a comet which would probably have been visible for several weeks in telescopes of moderate size. No doubt it happens quite often that a comet visits the solar system without being detected at all; but if once seen, usually only a few hours elapse until a score of telescopes have been pointed to it, at observatories scattered around the Earth.

Nevertheless, comets are certainly accorded a better welcome now than two or three generations ago. Perhaps it would not be citing too extreme a case to mention Comet 1827 I as an example of how comets were observed at that day. The definitive orbit of this comet has been published in *Astronomische Nachrichten,* No. 3830, by Doctor Strömgren. The comet was discovered by Pons, of Florence, on December 26, 1826, and observations were made of it there on December 27th, 28th, 30th, and 31st, but on no other dates. Evidently the news of the discovery did not get abroad until the middle of January, for the next observation was made on January 17th, by Harding, at Göttingen; eight other observations were secured at Bremen and Kremsmünster by January 26th, the last date on which the comet was seen. But the inadequacy of the data for computing an orbit does not appear until the character of the observations is examined. The Florence observations seem to be inferior to what one might make with the naked eye upon a sufficiently bright comet; the residuals obtained by comparison with a preliminary orbit average over ten minutes of arc, even after rejecting one observation whose residual is 46′. The single Göttingen place is hardly better, the residual in R. A. being 5′.8, and in declination 3′.6. The four Kremsmünster observations in their original form were very wild, but they were much improved by Dr. Strömgren's new reduction of them. The four observations at Bremen were made by Olbers, and are, of course, good for that day, but unfortunately they embrace a period of only four days. Thus the orbit of this comet rests on the eight observations made at Bremen and Kremsmünster, and these were all made between January 18th and January 26th.

Nova Persei.—The great usefulness of the Harvard photographs has again been shown by an important discovery with regard to the early history of *Nova Persei.* Father ZWACK, of the Georgetown College Observatory, some time ago called Professor PICKERING's attention to a faint star on one of the early Harvard plates, at or very near the position now occupied by *Nova Persei.* Careful measurements show that the two objects are in all probability identical, and furthermore it appears that the faint star was a variable, with a range of about one magnitude and a maximum brightness of the thirteenth magnitude. One other *Nova,* that of 1866 in *Corona Borealis,* is known to have existed before its outburst, having been recorded in the Bonn *Durchmusterung.*

This discovery with regard to *Nova Persei* tends still further to do away with the distinction between variable and temporary stars. Indeed, if it should be found that *Nova Persei* will again become variable there is little distinction, except in degree, between its fluctuations and those of *Mira Ceti,* for example.

It was stated in General Notes, No. 86 of these *Publications,* that *Eros* is the only exception to the rule that minor planets should have feminine names. Professor TURNER points out in *Observatory* that another exception is presented by planet (342), which is named *Endymion.*

Laws Observatory, of Missouri University, has adopted the method of publication by Bulletins, and No. 1 has been distributed. This is entitled "Observations and Elements of Comet *b* 1902 (PERRINE)," by Professor F. H. SEARES. The observations are 30 in number, and extend from September 4 to October 28, 1902. Upon these is based a computation of the orbit of the comet by an adaptation of LEUSCHNER's recent method.

Herschel's Nebulous Regions.—The elder HERSCHEL noted during his sweeps 52 regions "affected with nebulosity," and published in the *Philosophical Transactions* brief descriptions of them, with their approximate positions and dimensions. Doctor ISAAC ROBERTS has recently photographed all these regions with a 20-inch reflector and exposures of 90 minutes each. These should show, according to the estimate of Dr. ROBERTS, stars as faint as the sixteenth or seventeenth magnitude, but the result is reached that the nebulosity of only four of the regions is confirmed. This result is all the more surprising becausing HERSCHEL'S notes do not indicate that these four regions are more affected than some of the others. As it is hard to understand how HERSCHEL could be so greatly mistaken, and still more difficult to see how these photographs can be in error, a repetition elsewhere of Dr. ROBERTS'S survey would be most valuable.

Jan. 15, 1903.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, JANUARY 31, 1903, AT 7:30 P.M.

President PERRINE presided. A quorum was present. The minutes of the last meeting were approved.

The following new members were duly elected:—

LIST OF MEMBERS ELECTED JANUARY 31, 1903.

Mr. WM. GRANT . . . . 104 Sutter Street, S. F., Cal.
LIBRARY OF THE UNIVERSITY OF SOFIA . . . . Sofia, Bulgaria, Europe.
Mr JOHN L. McNAB . . . . Ukiah, Cal.

A committee to nominate a list of eleven Directors and Committee on Publication, to be voted for at the annual meeting, to be held on March 28th, was appointed as follows: Messrs. WM. H. LOWDEN (Chairman), JOS D. GRANT, GEO. C. EDWARDS, CHAS. NELSON, J. O'B. GUNN.

A committee to audit the accounts of the Treasurer, and to report at the annual meeting in March, was appointed as follows: Messrs. CHAS S CUSHING (Chairman), JOS. A. DONOHOE, L. H. PIERSON.

The following resolution was unanimously adopted:—

***Resolved*, That Mr. WM. M. PIERSON, on account of the exceptional aid, both professional and financial, which he has rendered this Society, is entitled to the gratitude of all its members and is deserving of such marks of esteem as this Board has the power to grant; and it is therefore further**

***Resolved*, That Mr. PIERSON be, and he hereby is, elected a Life Member of this Society.**

It was upon motion

Resolved, That the Reports of the U.S. Commissioner of Education contained in the Library be presented by this Society to the Library of the University of California.

AMENDMENT TO THE BY-LAWS.

The following amendment to the By-Laws was duly adopted by the consenting votes of nine Directors, namely, Messrs C. D PERRINE, A. O. LEUSCHNER, S. D. TOWNLEY, WM. M. PIERSON, CHAS. S. CUSHING, E. J. MOLERA, A. H. BABCOCK, F R ZIEL, Miss R. O'HALLORAN:—

ARTICLE VIII.

Each active member shall pay as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. No one shall be deemed an active member, or receive a diploma, until he has signed the register of members, or accepted his election to membership in writing, and paid his dues for the current year. Any member may be released from annual dues by the payment of fifty dollars at one time, and placed on the roll of life members by the vote of the Board of Directors. Any failure on the part of a member to pay his dues within six months after the time the same shall have become payable, may, at the discretion of the Board of Directors, be considered equivalent to a resignation.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE LECTURE HALL OF THE CALIFORNIA ACADEMY OF SCIENCES, JANUARY 31, 1903, AT 8 P.M.

President PERRINE presided. The minutes of the last meeting were approved.

The following papers were presented:—

The Total Light of the Stars, by Dr. S. D. TOWNLEY.
Planetary Phenomena for March aud April, 1903, by Prof. M. MCNEILL.

The Secretary read the names of new members elected.

Mr. BURCKHALTER, in behalf of the Comet Medal Committee, presented the Donohoe Comet-Medal to Prof. PERRINE for his discovery of Comet *b* 1902.

The President then introduced the lecturer of the evening Dr. S. D. TOWNLEY, who gave an account of his recent investigations in reference to the total light of the stars. An abstract of his paper is contained in this number of the *Publications*.

The meeting then adjourned.

OFFICERS OF THE SOCIETY.

Mr. C. D. Perrine	*President*
Mr. S. D. Townley	*First Vice-President*
Miss R. O'Halloran	*Second Vice-President*
Mr. Chas. S. Cushing	*Third Vice-President*
Mr. R. G. Aitken Mr. F. R. Ziel	*Secretaries*
Mr. F. R. Ziel	*Treasurer*

Board of Directors—Messrs. Aitken, Babcock, Campbell, Cushing, Leuschner, Molera, Miss O'Halloran, Messrs. Perrine, Pierson, Townley, Ziel.

Finance Committee—Messrs. Pierson, Cushing, Babcock.

Committee on Publication—Messrs. Aitken, Galloway, Schlesinger.

Library Committee—Mr. Townley, Miss O'Halloran, Mr. Brasch.

Committee on the Comet-Medal—Messrs. Campbell (*ex-officio*), Pierson, Burckhalter.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Felipe Valle.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

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OF THE
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ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY READ AT THE FIFTEENTH ANNUAL MEETING, MARCH 28, 1903.

BY C. D. PERRINE.

It has been the custom for the retiring Presidents to address the Society on the occasions of its annual meetings. The award of the Bruce Gold Medal since its foundation, and an account of the work of the recipient has occupied, naturally, the chief place in these annual addresses. As no award of the medal has been made this year, I shall take the opportunity to review the progress of the Society in certain directions, with a view to pointing out some of its most useful fields and urgent needs.

The formation of the Society was almost spontaneous, and the direct result of the solar eclipse of New Year's day, 1889, when so many of the amateur photographers visited the region of totality in northern California. At the time of its organization, the Astronomical Society of the Pacific was the only active astronomical association in the United States, amateur or professional.

One of the first acts of the Society was to commence a series of *Publications* to contain popular accounts of current astronomical work and observations made by its members. As there were at this time but two journals in America devoted entirely to astronomical science, there was also a wide and useful field for the Society's publications in printing original investigations. This field was at once occupied as fully as the conditions would permit. Although the Society was organized almost wholly of persons interested in astronomy as a pastime only, it now numbers many prominent scientists among its members, and there has been much substantial scientific work in its proceedings from the first. The result has been that its publications have taken and fill an honorable place with the scientific institutions and individuals of the world, as well as maintaining the original aim of the Society, to diffuse current astronomical information in a form to be understood by the non-professional.

Early in the history of the Society, substantial foundations began to come to it from its wealthy members. The first of these was the Comet-Medal established by JOSEPH A. DONOHOE. A number of medals and prizes for the discovery of comets had been awarded during the previous half-century. These were given principally by European rulers and one or two scientific societies, and were awarded in specific cases. There was no permanent foundation for any of them, and all have been discontinued. Mr. DONOHOE'S gift was sufficient to maintain a medal in perpetuity. This medal is intended solely as a recognition of the discovery of an unexpected comet, and in no way as a reward.

The Donohoe Comet-Medal foundation was soon followed by the gift of a fund by ALEXANDER MONTGOMERY for the purchase of the nucleus of an astronomical library and for its maintenance. With this beginning the library has grown rapidly, principally through accessions by gift from observatories and scientific societies, until it now numbers over twelve hundred bound volumes and a large number of pamphlets. One of the very useful fields for the Society is to own a complete astronomical library, and to have it available for reference purposes.

In 1897 Miss CATHERINE WOLFE BRUCE, who has done so much for astronomical science on both sides of the Atlantic, gave the Society a sum of money sufficient to maintain a gold medal, to be awarded to those astronomers who have done most to advance the science. The Bruce Gold Medal, like the Donohoe Comet-Medal, is international in character.

In 1892 it was decided to place the fees of the life members in a separate fund, so long as the member lived. At his death the fee was to be used for the general expenses of the Society. Previous to this time all such fees had been put into the General Fund. After 1892, however, all the fees received from life members were placed in the Life Membership Fund, and any surplus general funds at the end of the year were also transferred toward the representation of the full number of life members, until at present this fund contains $1,700. As there are seventy life members, the present balance is only about half as large as it should be. This fund is intended as a guarantee to the members who have paid their dues long in advance.

The Society has suffered the loss by death, during the past year, of several of its members. Two of them bequeathed substantial sums of money to the Society: Mr. MORRIS REIMAN, of Chicago, left the sum of $500, and Mr. JOHN DOLBEER, of San Francisco, the sum of $5,000. I believe that no conditions have been attached to either of these gifts. They can, therefore, be used in the way most beneficial to the Society. It is not too much to say that such bequests are of the highest possible value. They are extremely adaptable and thus available for a great variety of purposes.

Such bequests should be made of perpetual use, by treating them as endowments or expending them for some concrete purpose. In the present state of our Society, with so many funds already established for specific purposes; and the need for a larger yearly income, there can be no doubt as to the disposition that should be made of them. They should be invested in good interest-bearing securities and the incomes only used. Each fund should be kept entirely distinct, and should, of course, bear the name of the donor. The incomes should be expended, as far as possible, for some particular purpose, so that proper recognition may always be accorded and the usefulness of such gifts traced.

The income of the Reiman Fund may very properly accumulate for several years until there is sufficient to furnish a high-class illustration for one of the *Publications*. Such illustrations are badly needed.

The greater income from the Dolbeer Fund will fill a larger field. The most pressing need now is towards an enlargement of our *Publications* and a greater number of illustrations for them of the highest excellence. No better immediate use can be found for the income from this fund than to supply some of these urgent needs of the *Publications*. If these wants are supplied later through other channels,—and it is hoped that they will be,—the income of the Dolbeer fund would be relieved and could be applied to other purposes. I may mention some ways in which such incomes could be most usefully expended.

Our knowledge of comets, particularly of their origin and family history, is to be increased principally through observations of those which are permanent members of the solar system. Many periodic comets have been discovered, but a large proportion of them have been missed at subsequent returns to perihelion and entirely lost. The searching for these bodies at their predicted returns is usually done at some of the large observatories having powerful telescopes, and, recognizing the importance of the work, it is conscientiously prosecuted. In many cases where the return of such a comet has been missed it is undoubtedly because the comet has become too faint to be seen even with powerful telescopes. But it is probable that some comets, at least, have been missed because unknown disturbances in their orbits have occurred, which caused them to be so far from their predicted places as to be beyond the region searched. The field of a large telescope is so limited that it is only possible to sweep over a comparatively small area of sky in the time usually available for such searches. When near perihelion and at their greatest brightness, these comets are frequently on the opposite side of the Sun from the Earth, and so nearly in the same line, that only a short time is available after sunset or before sunrise for the search. It is therefore desirable for as many observers as possible to take part in the searches. Encouragement is needed to induce those not now engaged in such work to take it up. The best form for such encouragement would be money prizes for the re-discovery of such periodic comets as have been observed at only one apparition, or those which are of special importance and are likely to pass unobserved. The amount of the prize could be varied according to the importance of the discovery.

Another field which requires exploiting is that of simplifying the numerical operations in astronomical computations and adapting mechanism to the solution of problems which must be repeated many times. The growth of astronomical work has been so rapid that there is now in all observatories and computing bureaus a great amount of routine calculation.

Calculating-machines have been invented to perform the simple arithmetical operations and have proven most valuable. We need, however, to go a step farther and put some steel brains into them, so that they will perform all the operations in a given problem, *e. g.* the computation of ephemerides, reductions of star-places, etc. Many of these special problems can be solved by machinery, and the time has come to encourage its invention. This can best be done by offering substantial prizes for machines which will satisfactorily do specific pieces of work.

It is one of the functions of a scientific society to assist investigators and inventors in the solution of special problems. Instances of members of this Society supplying such aid are not wanting. I need only mention such names as MILLS, CROCKER, HEARST, BRUCE, DOLBEER, and PIERSON to recall some of them.

The wide field that is open to our publications has already been spoken of. This field is only partially occupied at present, owing to a lack of funds. The income from the members, after meeting the general expenses of the Society, is only sufficient to maintain the publications in their present quantity. A Publication Fund of $25,000 is badly needed to permit of the necessary expansion and improvement. The income from such a fund, together with the amount which would be available from the General Fund, would meet this demand.

Another of the ways in which the Society can be very useful is in creating and maintaining an interest in actual observation of the heavens. In San Francisco there are many people who are already interested in astronomy and many more who would become interested and find pleasure and instruction in looking at the wealth of objects which are to be seen with a telescope of some power. The matter of an observatory for the Society was broached a number of years ago and a site in Golden Gate Park secured. I take this occasion to again call attention to the desirability of such an establishment. An equatorial telescope of ten or twelve inches aperture, with the necessary accessories and a suitable dome and observatory building, would cost about $10,000.

I have spoken freely of some of the more important ways in which the Society can be aided financially, in the hope that some of our members, knowing of them, may be able to assist in supplying them.

The broadening influence of science, and particularly astronomy, cannot be overestimated. As the public school has become the birthright of every American boy and girl, so will a knowledge of science be looked upon in future years as a necessary part of their course of study and one of the most potent of civilizing forces.

Perhaps the most important of the fields open to our Society is that of diffusing a more general knowledge of astronomical science.

A suggestion has been made by one of our members which, if it can be carried out, would be most fitting and in many ways a benefit to the Society. It is that the Society become one of the affiliated institutions of the State University. It seems eminently proper that scientific societies should cluster around a great University.

It has been found that more or less confusion in regard to finances arose from the non-coincidence of our fiscal year with the calendar year. To obviate this difficulty two financial reports are rendered at this meeting, one covering the period from April 1, to December 31, 1902; the other from January 1, to March 31, 1903.

It seems to me that we should avoid, if possible, paying a deficit out of the income from the following year (which has its own proper demand). Accumulated deficiencies, which are possible in this way, will cause a stagnation and endanger the usefulness of the Society.

Article IX of the By-Laws has been amended so that the meetings of the Society are made more uniform and convenient.

To encourage students in universities and high schools to become members of the Society, special provisions have been made whereby their fees are reduced during such time as they are actually enrolled as students. It is hoped in this way to give many an opportunity of enjoying membership who otherwise would be debarred for several years.

It is highly desirable, as soon as arrangements can be made to do so, that the rooms and library of the Society be kept open during the greater part of each week-day. The library should be much more accessible than it now is.

At present there are but three meetings of the Society in San Francisco. These are public meetings. A system of informal meetings for reading and discussion, if inaugurated by the members residing in and about San Francisco, would be found very helpful. Such meetings could be held monthly, or weekly if desirable.

In conclusion, I wish to thank the officers and members of the Society for their cordial help and co-operation during the past year. Without such assistance my duties would have been much less easy.

MT. HAMILTON, CAL., March 16, 1903.

PARALLAX OF THE BINARY SYSTEM *DELTA EQUULEI.*[*]

BY W. J. HUSSEY.

The object of this communication is to present a value of the parallax to δ *Equulei* obtained by using as data the elements of the orbit derived from micrometrical measures and the relative velocity of the components in the line of sight furnished by spectroscopic observations. While the result given is merely provisional, one to be improved when better elements of the orbit are available, as they no doubt will be after two or three years more, yet it is thought that it has already a measure of certainty which places it in the list with the more accurately determined stellar parallaxes. Moreover, the manner of its derivation differs from previous determinations. The use of comparison-stars and the uncertainties of their assumed distances are eliminated. In theory the method leads to an absolute value of the parallax, and not to a relative one, as is necessarily the case when comparison-stars are employed.

The mathematical relations connecting the elements of the orbit of a binary, the relative velocity of its components in the line of sight, and the parallax of the system, have long been known. Applications have hitherto been wanting for the reason that no double stars had been found which furnished all the data needed. δ *Equulei* has proven an exception. The elements of its orbit are approximately known, and in 1901, at the time of the last periastron passage, the relative velocity of the components in the line of sight was so great that the spectra of the two stars were displaced to a measureable extent.

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[*] *Bulletin* of the Lick Observatory, No. 32.

In the *Monthly Notices* of the Royal Astronomical Society for March, 1890, Professor ARTHUR A. RAMBAUT has given the following simple formula for computing the parallax of a binary from the data here considered:—

$$\pi = \frac{l\, a^2 \sqrt{1 - e^2}\, \sin\, (\phi - \lambda)\, \sin\, i}{V P r \sqrt{1 - e^2 \cos^2 \phi}}.$$

In this equation P denotes the periodic time, a the mean distance, e the eccentricity, i the inclination, r the radius vector, λ the angle between the line of nodes and the major axis of the true ellipse, ϕ the angle between the tangent to the orbit and the major axis, V the relative velocity of the components in the line of sight as furnished by the spectroscopic observations, l the velocity of the Earth in its orbit, and π the parallax of the system.

The elements of the orbit of δ *Equulei* are still imperfectly known. A nearly continuous record of the motion of the companion during the next three years is necessary to remove effectively the uncertainties which still exist in their values. Eight times since the discovery of this binary the companion has passed over the arc which it will describe during the next three years, and numerous observations relate to this portion of the orbit. But the measures are more or less discordant, and on this account additional ones are required to fix with certainty the direction and magnitude of the greatest apparent distance. When these measures are obtained and the elements of the orbit revised we shall have the data which will give an accurate value of the parallax of the system. A consideration of the material at present available appears to show that the changes which will probably take place in the elements due to the revision of the orbit will not greatly alter the value of the parallax which may now be derived, and it is on this account that a provisional value is here presented.

During the past three years this binary has been followed closely at the Lick Observatory, and much has been done to advance our knowledge of its orbit. It has been shown that the periodic time is about 5.7 years; that the last epoch of periastron passage was about 1901.5; that the apparent distance at periastron is about 0″.15; that the inclination is greater than given by the elements which I printed in the *Publications* of the Astronomical Society of the Pacific for December, 1900, and afterwards in Volume V of the *Publications* of the Lick Observatory, being perhaps as much as 82° or 83°; and that the mean distance is probably a little larger than given by those elements. Further, it is known that the line of nodes and the projection of the major axis of the orbit are nearly coincident.

If we retain the line of nodes and the angle between the line of nodes and the major axis of the true ellipse as given by my published elements, and put the mean distance equal to 0″.28 and the eccentricity equal to 0.46, we get 0″.151 and 0″.409 as the periastron and apastron distances.

The relative velocity of the components in the line of sight at the epoch of periastron passage, as determined by the observers using the Mills spectrograph, was about 20.5 miles per second. At the same time the Earth's orbital velocity was about 18.2 miles per second. At periastron ϕ becomes 90° or 270°, and with $\lambda = 179°$, we have $\phi - \lambda = 91°$. Substituting these values in Professor RAMBAUT'S formula we get

$$\pi = 0''.071.$$

It is evidently impossible to give the probable error of this result. Some of the quantities upon which it depends are much better determined than others. It happens that those which appear to be the most uncertain may vary considerably without greatly affecting the resulting value of the parallax. For example, considerable variations may take place in the values of i and λ without greatly changing the values of sin i and sin $(\phi - \lambda)$ which appear in the formula. Of the other quantities those which appear the least certain are the mean distance and the eccentricity. From a consideration of all the past measures it appears highly improbable that the apastron distance can be as much as 0″.05 greater or less than the value used above. If we vary the apastron distance and eccentricity together, so as to keep the already well-determined periastron distance constant, and further retain the other elements of the computation as used above, we shall find that the apastron distance and parallax increase together, but the former at about four times the rate of the latter. From this consideration it appears improbable that the parallax will be altered so much as 0″.012, owing to changes which take place in the values of *a* and *e* due to the revision of the elements of the orbit.

The mass of the system corresponding to the parallax given above, and the mean distance and periodic time used in its derivation, is 1.89, the mass of the Sun being taken as unity. The components of this pair are slightly unequal in brightness, and perhaps also in mass. One may be as massive as the Sun, but it can not much exceed it.

The mean distance at which these stars perform their revolutions is about four times that of the Earth from the Sun. But owing to the eccentricity of the orbit the range in distance is enormous. At periastron the stars are separated by a space only a little greater than two astronomical units, while at apastron it is five of these units.

It would form an interesting analytical problem to investigate the effect of tidal action upon the relative orbit in this system. The data are pretty well ascertained. Broadly speaking, the stars have spectra of the solar type, and being comparable with the Sun in mass, it would seem not unreasonable to assume that their densities are approximately the same as that of the Sun.

February 23, 1903.

ASTRONOMICAL OBSERVATIONS IN 1902.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

VARIABLE STARS.

*Z Cygni.**

Jan. 1: Z invisible.
5: id.
11: id.
13: faint < e.
16: id.
June 1: = b.
28: < c.
> d.
Sept. 7: invisible.
29: faint < e.
Oct. 8: id.
Oct. 12: id.
21: id.
25: id.
28: id.
Nov. 2: id.
20: id.
21: id.
30: = d.
Dec. 17: > b.
< a.
20: id.

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* *Vide* the sketch in the *Publications* A. S. P., No. 48, page 69.

*S Ursæ majoris.**

Jan. 1: S one step > d.
5: = d.
7: id.
11: id.
13: id.
16: id.
21: id.
30: one step < e.
Feb. 3: two steps < e.
8: id.
15: three steps < e.
22: $\begin{cases} < \text{e.} \\ > \text{f.} \end{cases}$
Mar. 3: = f.
7: id.
10: $\begin{cases} < \text{f.} \\ > \text{g.} \end{cases}$
12: one step > g.
22: = g.
24: id.
28: < g.
Apr. 5: id.
6: id.
9: id.
14: id.
June 1: $\left\{ \begin{matrix} <\text{e} \\ >\text{f} \end{matrix} \right\}$ nearest e.
28: = d.
Aug. 9: $\left\{ \begin{matrix} <\text{c} \\ >\text{d} \end{matrix} \right\}$ the middle.
11: two steps > d.
26: id.
Aug. 28: three steps > d.
Sept. 1: one step > d.
5: = d.
6: id.
7: id.
13: $\begin{cases} > \text{e.} \\ < \text{d.} \end{cases}$
17: = e.
18: id.
21: two steps < e.
22: id.
27: $\left\{ \begin{matrix} <\text{e} \\ >\text{f} \end{matrix} \right\}$ the middle.
29: nearest f.
Oct. 3: one step > f.
8: = f.
12: id.
21: id.
25: id.
28: id.
Nov. 2: < g.
17: invisible.
18: seen < g, air very clear.
19: id.
20: invisible.
21: 11th mag.
30: utmost faint.
Dec. 17: id.
20: > g.
21: id.

T Ursæ majoris.†

$\left. \begin{matrix} \text{Jan. 1} \\ \text{Mar. 3} \end{matrix} \right\}$ *T* invisible.
Mar. 7: = g.
10: id.
12: = f.
22: = e.
24: $\begin{cases} > \text{e.} \\ < \text{d.} \end{cases}$
28: = d.
Apr. 5: = b.
6: id.
Apr. 9: id.
14: one step < a.
22: = a.
26: $\begin{cases} > \text{a.} \\ = \text{b in the sketch of } S \textit{ Ursæ}. \end{cases}$
June 1: five steps > a.
28: $\begin{cases} < \text{b.} \\ > \text{c.} \end{cases}$
$\left. \begin{matrix} \text{Aug. 11} \\ \text{Oct. 28} \end{matrix} \right\}$ invisible.

---

* *Vide* the sketch in the *Publications* A. S. P., No. 73, page 56.

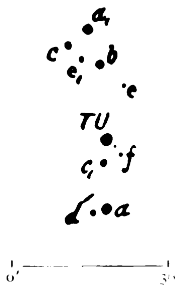
† *Vide* the sketch in the *Publications* A. S. P., No. 22, page 63.

Nov. 2: faint, < g.
17: one step < g.
18: id.
19: id.
20: id.
21: id.
29: = f.
Nov. 30: id.
Dec. 11: = d.
17: = b.
20: > b.
< a.
21: = a.

*W Pegasi.**

Jan. 5: W < h.
11: very faint.
13: a little increased, yet < g.
27: id.
30: almost = g.
Aug. 28: = h.
Sept. 1: id.
7: id.
Sept. 14: Almost invisible.
21: id.
27: id.
Oct. 3: id.
28: < h.
Nov. 18: id.
21: id.
30: id.
Dec. 20: id.

TU Cygni.



Jan. 1: TU < f (= 10^m).
11: id.
16: id.
June 1: = f.
Sept. 7: = c.
14: one step < b.
16: id.
17: id.
Sept. 18: = b.
21: one step > b.
22: id.
24: id.
Sept. 27: > b.
< a.
29: id.
Oct. 3: = a.
8: < a.
> b.
12: id.
21: = a.
25: id.
28: < a.
Nov. 2: id.
21: < b.
> c.
30: = c.
Dec. 17: = f.
20: < f.

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* *Vide* the sketch in the *Publications* A. S. P., No. 60, page 23. (*h* is the little star in the line between a_2 and *e*.)

Nova Persei.

	h.	m.
Jan. 1	6½ P. M.	7.2
5	6	7.5
6	6	7.4
7	8	7.4
11	6	7.4
12	10½	7.4
13	8½	7.4
14	7	7.4
16	6	7.6
21	6	7.6
27	9	8.0
30	8	7.7
31	8	8.1
Feb. 8	10	7.6
10	9½	7.6
15	7½	7.8
22	8½	7.9
Mar. 7	9	7.9–8.0
8	8	8.0
10	8	8.0
10	10	8.0
11	8½	8.2
12	8	8.2
22	8	8.0
24	8	8.0
27	8	8.0
28	9½	8.0
Apr. 5	8½	8.4
6	8½	8.0
9	8½	8.2
14	9	8.1
22	10	8.2
Apr. 26	9	8.4
Aug. 11	12	9.0
26	9	9.0
28	9	9.0
Sept. 1	9	9.1
5	9	9.1
7	11½	9.1
13	8	9.1
14	9	9.2
16	9	9.1
17	8	9.1
18	8	9.2
19	8	9.2
22	9	9.2
24	8	9.1
27	7½	9.2
29	9½	9.2
Oct. 3	8	9.2
12	8½	9.2
21	8	9.2
25	7	9.2
28	8	9.2
Nov. 2	9	9.2
17	6½	9.2
18	6	9.2
21	6	9.2
29	7½	9.2
30	5½	9.2
Dec. 11	5½	9.0
17	6½	9.3
20	5½	9.2
21	6	9.2

The Star BD 20° 1083.

This star has shown remarkable variations in the year 1902. For the comparisons I have used the following stars: *A, B,* and *b,* the variable being named *a.* The BD magnitudes are added here, but it may be noted that I always see A > B.

A = BD 20° 1095, 7.4^m
B = BD 20° 1093, 7.3
a = BD 20° 1083, 7.7
b = BD 20° 1073, 8.2

NOTE.—In Georgetown College's Chart II I have found among other discrepancies, No. 17 decidedly *less* than No. 20. The chart has No. 17 = 8.8 mag.; No. 20 = 8.9 mag.

When the ocular-tube is screwed out until the stars appear as pale disks, it is least difficult to state the variation.

Jan. 11: a one step > b.
30: distinctly > b.
Mar. 7: particularly bright, > b.
8: = A.
10: id.
11: id.
24: id.
27: id.
28: id.
Apr. 5: = B.
6: = A.
9: = B.
14: id.
26: id.
Oct. 25: < b.
Nov. 20: = b.
Dec. 11: > b.
17: < b.
20: id.

Occasionally I also looked out for other variables. *S Vulpeculæ* and *S Draconis* do not seem to have changed their light.

Eclipse of the Moon.

On April 22d, at sunset, according to calculation, the eclipsed Moon should have been observable at the eastern horizon, but on account of mist the red Moon was not seen until it had ascended to an altitude of 5 degrees. The shadow was touching:—

Tycho (west) at	8^h	57^m P. M.
Copernicus (east) at	8	59.5
(west) at	9	1
Plato (east) at	9	9
(west) at	9	10.5
Posidonius (west) at	9	28
Mare Crisium (west) at	9	42
End of eclipse	9	45

*Shooting Stars.**

Of the meteors observed simultaneously at Uranienborg, Copenhagen, and Odder in August, 1902, only ten yielded the data necessary to calculate their height above the Earth's surface. For these we have the following results:—

No.	Height at the Beginning. Kilometers.	Height at the End. Kilometers.	Real Length of the Path. Kilometers.
1	119	...	..
2	...	110	..
3	...	77	..
4	112	54	72
5	117	90	31
6	57	...	..
7	92	...	..
8	139	86	65
9	87	82	44
10	101	...	..

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* *The author sends details of observations of 44 shooting stars which were made on the nights of August 9-12, 1902.* These we have been obliged to omit.—THE EDITORS.

FIREBALLS.

In the past year twenty-six fireballs have been seen from stations in Denmark and surrounding countries, as follows: *

No.	Time. h m	Beginning.	End.	Mag.	Station.	Notes.
1	Jan. 6, 8 41 P. M.	NW.	......	....	Copenhagen ...	Train. Length, 35° to 40°.
5	10, 9 30	E. to W.	in Southern sky.	♀	Göteborg	Blue-white meteor.
7	Feb. 8, 4 45	N. to S.	in Eastern sky.	....	Hobro.........	A beautiful fireball appearing in daylight.
8	14, 6 11 A. M.	SE.	SW. in Southern sky.	....	32 stations in Denmark.	A large meteor exploding into five parts, with trains within a common large train. The largest fragment was as bright as *Venus*. The path, about 400 kilometers long, was traversed in 20 seconds to 25 seconds.
10	Apr. 2, 1 45	SSW.	NNE., passing zenith.	....	Copenhagen ...	Lighted up the whole region. Blue-white, exploding into four parts.
11	6, 5 54 P. M.	......	SE. 45° altitude.	....	Nyköbing S....	White meteor, seen by sunlight.
13	15, 9 10	*Denebola.*	*Perseus*, between *Pollux* and the Moon.	♀	Odder.........	The first 5 degrees of the train were reddish. When passing *Pollux*, the fireball exploded into two parts. Duration, 20 seconds. Observed by EMANUELA KÖHL. Also seen at other places; disappeared above the North Sea.
14	20, 10 00	......	Just East of the Moon.	1-10☾	Copenhagen....	Train 3 degrees long; duration 3 seconds.
20	Sept. 10, 11 5	......	25° altitude, SE.	♃	Kolding	The meteor was red, its train green. Path 10 degrees long.
23	Nov. 9, 5 30	NW. to SW.	in Northwestern sky.	....	Lemwig	Exploded into two, and these afterwards into several parts. Slow. Train. Also seen at Tönder, Hamburg, and other stations.

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* The details of the ten most interesting of these meteors are here given.—THE EDITORS.

A BRIEF ACCOUNT OF THE D. O. MILLS EXPEDITION TO CHILE.

By W. W. Campbell.

The D. O. Mills Astronomical Expedition from the Lick Observatory, University of California, will sail from San Francisco to-day* with destination in the neighborhood of Santiago, Chile. The work of the expedition will be largely technical, yet its purpose is to contribute to the solution of a perfectly definite problem.

It is well known that the observed positions and motions of celestial objects are influenced not only by the motions of the objects themselves, but also by motions of the observer. Not including several minor disturbances, the observer's motion is made up of three components:—

(1) That due to the rotation of the Earth on its axis. The elements of this diurnal motion are well known, and its effects can be eliminated completely from the observations.

(2) That due to the annual revolution of the Earth around the Sun. The form of the Earth's orbit is very well known, but there is at present an uncertainty of from one fourth to one half of one per cent in the size of the orbit. This introduces a slight uncertainty in the observer's speed, which is troublesome in a few cases. It is hoped that as a result of recent observations of the planet *Eros* we shall soon be able to eliminate the greater part of this uncertainty.

(3) That due to the motion of the solar system (Sun, planets and their moons) through space. The elements of this motion are not well known. In fact, a general knowledge of them constitutes one of the most pressing problems in astronomy, and it is to contribute to the solution of this problem that the Mills Expedition to the southern hemisphere has been organized.

More than 100 years ago Sir William Herschel, from a consideration of the apparent motions of the few stars then accurately observed, came to the conclusion that the solar system is moving in a straight line approximately toward the constellation *Hercules.* This was in fact one of the shrewd guesses for which HERSCHEL is justly famous. Later solutions made by other astronomers, using the steadily increasing number of observed stars, have confirmed the approximate correctness of HERSCHEL'S result as to the point toward which the solar system is moving. They have, I think, without exception, located this point either in *Hercules* or in *Lyra.* Nevertheless, the various solutions leave an uncertainty of at least ten or fifteen degrees as to the direction of the motion.

---

* February 28, 1903.

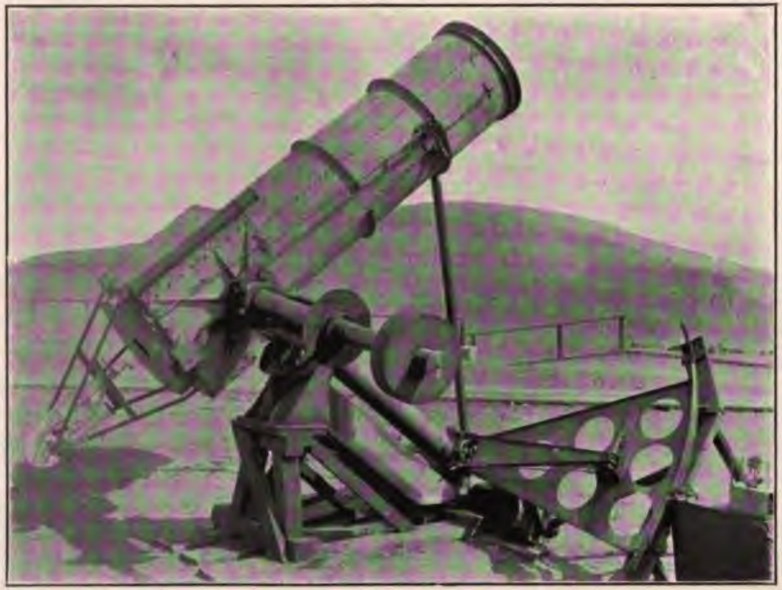
Our knowledge of the speed of the solar system has been much less satisfactory. HERSCHEL had almost no information as to the distances of the stars, but by making certain assumptions as to their distances he was led to the conclusion that the speed of the solar system is probably in the neighborhood of ten miles per second. Other discussions of the question have led to the assignment of values ranging from as low as five miles to as high as twenty-five miles per second. All these solutions were based upon the observed directions, and changes in the observed directions, of the stars, and involved assumptions as to the unknown stellar distances.

The development of the spectroscopic method of measuring stellar velocities in the line of sight of the observer has placed in our hands a means of making decided improvements in our knowledge of the solar motions, since this method is entirely independent of stellar distances. It is exceedingly simple in theory, but one of extraordinary difficulty in practice. It is based upon the fact, well known to students of physical science, that if a star is approaching the observer its spectrum will be shifted slightly as a whole toward the violet from its normal position, and if the star is traveling away from the observer its spectrum will be shifted slightly as a whole toward the red end.

These displacements of the spectra, due to the velocities of the stars, are on so minute a scale that the errors of observation may readily exceed the magnitude of the quantities to be observed. Fortunately the thorough understanding of the problem, reached through what have been bitter experiences to some observers, has made it possible at the present time to measure stellar velocities with a high degree of accuracy. The displacements of the spectra referred to, measured with the instruments now in use for that purpose, amount to only the thousandth part of an inch for a speed of fourteen miles per second. Yet we are able to measure spectrum plates very nearly to the one-hundredth part of a thousandth of an inch,—that is, nearly to the one one-hundred-thousandth of an inch. The evolution of instruments and methods and the precautions taken to enable us to reach this degree of refinement form an interesting part of the history of astronomy, but need not be considered here.

The velocities of some four hundred of the brighter stars have in the last seven years been measured with the D. O. Mills spectrograph attached to the great Lick telescope. These stars are distributed more or less uniformly over the three fourths of the sky visible from Mt. Hamilton. Two years ago I combined the results from these stars in an attempt to determine the elements of solar motion. It is evident that while the individual stars have individual motions, one moving in one direction, another in another direction, nearly all of them apparently independent of one another; yet if the solar system is moving toward a given point in the sky the stars in that portion of the sky will, on the average, appear to be approaching the solar system; and similarly, that the stars in the exactly opposite portion of the sky will appear to be moving away from the solar system. Conversely, if the velocities of the stars in all parts of the sky be known, it is possible by mathematical analysis to determine a point in the sky such that the stars within a concentric area will have the maximum velocity of approach to the solar system; and in the corresponding opposite area a maximum velocity of recession; the stars in other areas of the sky having systematically smaller speeds of approach or recession.

The solution referred to led to the result that the solar system is moving approximately in the direction of the southern boundary of the Lyre, with a speed of twelve and a half miles per second. There is no doubt that this result for speed is very close to the truth; but it is reasonably certain that the direction of the motion is somewhat in error. The weakness of the solution lies in the fact that the observed stars are not distributed uniformly over the entire sky. The region from thirty degrees south of the celestial equator to the south pole of the sky is not represented at all in the observational data.



THE D. O. MILLS REFLECTOR AND SPECTOGRAPH.

This deficiency affects the direction of motion vastly more than it does the speed. Before a satisfactory solution of this great problem can be made the stars in the one fourth of the sky around the south pole must be observed by methods similar to those employed at Mt. Hamilton.

It has for nine years past been my desire to organize at the proper time a spectroscopic expedition to the southern hemisphere for the purpose of securing these observations. Two years ago, the problems under solution and the needs of such an expedition were brought to the attention of Mr. D. O. MILLS, who promptly and most generously expressed the great pleasure it would afford him to provide funds for constructing the apparatus, for employing the astronomers, and for meeting the necessary expenses.

The telescope constructed for this purpose is shown in the accompanying illustration set up on Mt. Hamilton in the rear of the observatory for adjustment and trial. It is a reflecting telescope of Cassegrain form. I may remark that in a refracting telescope, such as the great Lick refractor, the rays of light from celestial objects pass through polished-glass lenses at the upper extremity of the telescope tube, and are brought to a focus at the lower extremity, where the eye of the observer is placed.

In this reflecting telescope, the upper end of the tube is open. The rays from a star pass down the tube to its lower extremity, where they fall on a silver-on-glass mirror, 37¼ inches in diameter. Its accurately polished surface, 36½ inches in diameter, has the curve of a parabola. The beam of parallel light from a star, upon striking the mirror, is reflected back, and an image of the star would be formed in the focus 17½ feet above the mirror; but a silver-on-glass hyperbolic convex mirror 10 inches in diameter, placed 4½ feet inside the focus, and just within the upper end of the tube, intercepts the rays. This small mirror is held in place by steel webs, which occult a small portion of the light from the star, but otherwise do no serious injury. This mirror turns the rays backward through a five-inch hole in the center of the large mirror, where they are brought to a focus a short distance below the telescope-tube, exactly on the slit of a powerful photographic spectroscope. The spectroscope is held in position by a steel truss. In theory it resembles the Mills spectroscope now in use at the Lick Observatory, but in reality it embodies many new departures based upon our seven years' experience with the older instrument. When in use the spectroscope will be completely inclosed in a temperature-case of aluminum, lined with hair felt and supplied with automatic electric heating apparatus, in order that it may be maintained throughout the night's observation at a constant temperature. The photographs upon which the results depend are of such exceeding delicacy that the small range of temperature which ordinarily occurs throughout the night would, if such precautions were not taken, render them almost valueless.

The mounting of the telescope was designed in general by the writer and in detail by the San Francisco firm of HARRON, RICKARD & MCCONE. It was constructed in the shops of the Fulton Engine Works at Los Angeles. The optical parts of the telescope and spectroscope are from the well-known shops of the JOHN A. BRASHEAR COMPANY, Allegheny, Pa. The instruments will be covered by a modern thirty-foot steel dome, constructed by the WARNER & SWASEY COMPANY, builders of the great Lick telescope.

The dome and instruments will be mounted on the summit of one of the low hills near Santiago, where they will remain for two or three years. It is planned to measure the velocities of three or four hundred of the brighter stars in the southern sky. The photographs will be sent to the Lick Observatory for measurement and discussion. It is confidently expected that a combination of the spectroscopic results obtained at Mt. Hamilton and Santiago will lead to a very satisfactory solution of the troublesome problem of the motion of our solar system through space.

There is little doubt that, as in the Mt. Hamilton observations, the discoveries made as by-products of the investigations will rival in scientific interest the results which comprise the main purpose of the work. One or two of these by-products may be mentioned. It was found, for example, that at least one star in seven, and probably a very much larger proportion, is attended by invisible companions. This is in addition to the companion-stars visible in ordinary telescopes and known to astronomers as double stars. For instance, the North Pole star, which has perhaps been under observation more than any other for hundreds and thousands of years, was discovered, four years ago, to have two dark, invisible companions, making it a triple system; or, counting the distant, well-known visual companion, a quadruple system.

Great interest has been taken in the plans of the Mills Expedition by astronomers and others. A recent important committee, reporting upon plans for astronomical progress, gave recognition to the fact that the Mills Expedition from the Lick Observatory would be the first to undertake observations of this kind in the southern hemisphere, and expressed the opinion that it would be well if at least one more similar expedition could be dispatched to occupy this neglected field.

The importance of this line of work and the interest taken in it may perhaps best be expressed by referring to the fact that nearly all of the great refracting telescopes of the northern hemisphere have been engaged in it with greater or less degrees of success.

The Mills Expedition will be in charge of Acting Astronomer WILLIAM H. WRIGHT, who has ably assisted in the observations with the Mills spectrograph at the Lick Observatory in the last six years, and to whose valuable suggestions and help much of the success of the work is due. Mr. WRIGHT was graduated from the University of California in 1893. He will be accompanied by Assistant H. K. PALMER of the class of 1898, who was for four years on the Lick Observatory staff as fellow, and who is at present an instructor in the Berkeley Astronomical Department.

The Government of Chile has taken official notice of the coming of the expedition, and has generously offered to further its purposes in every way possible.

D. O. MILLS has taken a deep interest in the work of the Lick Observatory since his appointment thirty years ago as a member of Mr. LICK's first board of trustees, and he has contributed to its needs on four occasions in the past decade. I confidently expect that the results obtained by the expedition to Chile will be worthy of his splendid gift and of the observatory and university under whose auspices the work is undertaken.

VARIABLE STARS.

By Rose O'Halloran.

In the four-inch Brashear telescope used for the following observations, stars of twelfth magnitude are generally at the limit of visibility, but on exceptionally clear nights the light-gathering power no doubt includes fainter stars, though it is uncertain if those of thirteenth magnitude are within its range. The powers used were from about 40 to 200, according to the condition of the atmosphere.

W Lyræ.

This variable having decreased from the maximum of January, 1902, to 9.4 in the following March, as published in No. 84, *Publications A. S. P.*, has since waned and increased as follows:—

1902.		
May	8.	Invisible.
	27.	Invisible.
June	1.	Invisible.
	2.	11.5 mag.; brighter than *t* of 12th mag.
	8.	Nearly of 11th mag.
	14.	Of 11th mag.
	16.	Of 11th mag.
	23.	Nearly equal to *g* of 10th mag.
	25.	Slightly brighter than *g*.
	28.	Equal to *g*.
July	1.	Brighter than *g*, less than *e* of 8.8 mag.
	4.	Slightly brighter than *e*, less than *a* of 8.6 mag.
	7.	Equal to *e*.
	10.	Between *e* and *p*. The latter is 9.4.
	15.	Between *e* and *p*.
	16.	*e* is about two-tenths brighter than *W*. On account of these fluctuations, the hour of observation is noted hereafter.
	21.	8.50 P. M. Equal to *e*.
	22	8.50 P. M. It is brighter than *e* but less than *a*.
	24.	8.30 P. M. More distinctly brighter than *e*, but still less than *a*.
	30.	8.55 P. M.
Aug.	1.	8.42 P. M.
	14.	8.15 P. M. After two cloudy weeks, *W* was seen to be brighter than *a* and equal to *n* of 8.1 mag., which is not far from the usual maximum of this variable. Further observation was unavoidably deferred until the constellation reappeared northeast in the morning sky.

Dec.	28.	5.45 A. M.	Discernible only in a high power. Probably of 12th mag.
	29.	6.10 A. M.	12th mag. This is the date of predicted minimum. The morning is clear.
1903.			
Jan.	29.	6.05 A. M.	Moonlight and rainy weather hindered observations for some weeks. *W* is two or three tenths brighter than *g*.
Feb.	5.	6.00 A. M.	Equal to *p*.
	15.	5.35 A. M.	Brighter than *p*, not fully equal to *e* It is probably of about 9th mag.
	21.	6 00 A. M.	Equal to *e*.
	28	5.34 A. M.	Equal to *a*. The morning is rather clear.
March	6.	5.45 A. M.	Equal to *a*, not equal to *n*.
	9.	5.42 A. M.	Equal to *a*. It has not yet attained its maximum brightness.

V Orionis.

Jan.	29.	Invisible. Night not very clear.
Feb.	1.	Barely discernible. Probably of less than 11.5 mag.
	12.	Barely discernible. Probably of less than 11.5 mag.
	25.	Invisible.
	26.	Invisible.
March	3.	Invisible.
	6.	Indiscernible. Half-moon is near. This is the date of predicted minimum.
	8.	Indiscernible. Moonlight.

S W Cygni (formerly designated *U^3 Cygni*, and sometimes *V^3 Cygni*).

For the sake of uniformity, this miniature of *Algol* has been rechristened, and will be described in future records as *S W Cygni.*

1902.			
Jan.	27.	6.00 A. M.	Equal to *f* of 9.2 mag.
Feb.	12.	5.45 A. M.	Equal to *d* of 9 6 mag.
	22.	5.15 A. M.	Not fully equal to *a* of 8.6 mag.
May	27.	9.54 P M.	Nearly equal to *a*
June	1.	9.30 P. M.	Brighter than *o* of 10 9 mag.
	2.	9.25 P. M.	Nearly equal to *a*.
	7.	9 30 P. M.	Between *a* and *f*.
	8.	9.20 P. M.	
	13.	9.15 P. M.	
	14.	9.30 P. M.	
	16.	9.20 P. M.	
	24.	9.28 P. M.	Of 12th mag.
	25.	9 25 P. M.	Scarcely more than 12th mag.

June	26.	10.00 P. M.	Nearly equal to *a*.
	28	10.00 P. M.	Still nearer to the brightness of *a*.
July	1.	9.12 P. M.	Between *a* and *f*.
	4.	9.18 P. M.	
	7.	9.05 P. M.	
	9.	9.12 P. M.	
	10.	9.18 P. M.	
	12.	9.13 P. M.	
	16.	9.08 P. M.	
	21.	9.15 P. M.	
	22.	9.00 P. M.	
	29.	8.30 P. M.	
	30.	8.40 P. M.	Nearly as bright as *a*.
	31.	9.30 P. M.	Nearly as bright as *a*.

The continued sameness was rather unusual, but being familiar with the field of view, I feel no uncertainty about it.

Y Virginis.

1902.

April	10.		It is of about 10th mag.
	13.		Of 9.5 mag.
	24.		Of 9th mag.
May	2.		About 8.8 mag.
	8.		About 8.8 mag.
	11.		Of 9th mag.
	12.		Date of maximum.
	29.	8.35 P. M.	Equals *c* of 9.5 mag.
	30.	8.45 P. M.	Equals *d* of 10.5 mag.
	31.	9.00 P. M.	*d* two tenths brighter than var.
Aug.	1.	9.05 P. M.	*d* two tenths brighter than var.
	2.	9.00 P. M.	Equal to *n* of 10.9 var.
	14.	8.35 P. M.	Probably not far from 12th mag., which is the usual limit of the telescope used.

W Aurigæ.

1902.

Oct.	28.	Brighter than *a*, less than *c*. Probably of 9.3 mag.
Nov.	1.	Brighter than *a*, less than *c*. Probably of 9.3 mag.
	3.	Equal to *a*.
	11.	Equal to *a*.
	18.	Fainter than *a*, brighter than *k* and *l*, with which it forms a triangle. About 10.5 mag.
	22.	Fainter than *a*, brighter than *k* and *l*.
	26.	Seems nearly equal to *a*.
Dec.	1.	Less than *a*, scarcely brighter than *l* of 11th mag.
	10.	Equal to *k*, classed as 12th mag.
	16.	Invisible. This maximum of October seems to have been unexpected.

S S Cygni.

A brief maximum of this interesting star was observed as follows:—

1902.

June	2.	9.35 P. M.	Invisible.
	24.	9.23 P. M.	
	25.	9.20 P. M.	
	26.	9.43 P. M.	
	28.	9.20 P. M.	
July	1.	9.15 P. M.	
	4.	9.21 P. M.	About 12th mag.
	7.	9.50 P. M.	
	10.	9.15 P. M.	
	12.	9.15 P. M.	
	13.	9.10 P. M.	
	15.	9.15 P. M.	Equal to *a* of 9.6 mag. Brighter than others, except *b*, in the triangular group around it.
	16.	9.05 P. M.	About two tenths brighter than *a*.
	21.	9.10 P. M.	Equal to *a*. Full moon.
	22.	9.10 P. M.	*a* two tenths brighter than the variable.
	29.	8.35 P. M.	Var. equals *c* of 9.5 mag.
	30.	8.45 P. M.	Var. equals *d* of 10.5 mag.
	31.	9.00 P. M.	*d* two tenths brighter than var.
Aug.	1.	9.05 P. M.	*d* two tenths brighter than var.
	2.	9.00 P. M.	Equal to *n* of 10.9 mag.
	14.	8.35 P. M.	It is about 11.5, or 12th mag.

S Tauri.

The minimum of *S Tauri,* expected on February 10th, occurred somewhat earlier, as at that stage it is invisible in a 4-inch lens.

1903.

Jan.	29.	About 10.5 mag.
Feb.	1.	10.2 mag. It is slightly increased.
	10.	In moonlight it seems of 10th mag., being equal to the adjacent stars.
	12.	In moonlight it seems of 10th mag.
	19 and 24.	Brighter than 10th, of 9.7 mag.
March	3.	It is of about 9.5 mag.
	6.	About 9.5 mag. Moon near by.
	8.	About 9.5 mag. Moonlight.

R Tauri.

1902. On November 19th, December 1st, 20th, 24th, 27th and 28th, this star was invisible.

1903.
Jan. 29. Of 11th mag. Dimmer than *S Tauri* in the same field of view.
Feb. 1. About 10.2 mag., but dimmer than s.
10. 9.5 mag., brighter than s.
12. Not far from 9th mag.
19. Brighter than 8th, probably 7.8 mag.
24. Brighter than 8th.
March 3. Not so bright, probably of 8th mag.
6. Probably of 8th mag. Half moon near.
8. Probably of 8th mag. Moonlight.

S Ursæ Minoris.

Date of expected maximum, May 9, 1902.

1902.
April 8. 9th mag.
9. 9th mag.
19. 8.5 mag.
26. 8th mag.
May 1. 8.5 mag.
8. 8.5 mag.
10. 8.5 mag.
14. 8.5 mag.

T Ursæ Majoris.

1902.
March 30. Equal to *k* of 9th mag.
April 8. About 8.8 mag.
13. Of 8th mag.
19. About two tenths brighter than 8th mag.
26. About two tenths brighter than 8th mag.
May 1. About two tenths brighter than 8th mag. Before the date of maximum brightness, May 21st, it had gone out of view.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1903.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter, May	3,	$11^h 26^m$ P.M.	First Quarter, June	2,	$5^h 24^m$ A.M.
Full Moon, "	11,	5 18 A.M.	Full Moon, "	9,	7 8 P.M.
Last Quarter, "	19,	7 18 A.M.	Last Quarter, "	17,	10 44 P.M.
New Moon, "	26,	2 50 P.M.	New Moon, "	24,	10 11 P.M.

The Sun reaches the solstice and summer begins June 22d, 7 A. M., Pacific time.

Mercury presents the best aspect of the year for naked-eye visibility during May. It is an evening star, and comes to its greatest east elongation on May 10th. It is then 21° 31′ east of the Sun, a distance about 4° greater than at the east elongation of January; but it is also several degrees north of the Sun, and this increases the interval between the setting of the Sun and the planet. For the first half of the month this interval is from an hour and a half to an hour and three quarters, and the planet can be easily seen on any clear evening in the twilight. After that *Mercury* rapidly approaches the Sun, and comes to inferior conjunction on June 3d. During the remainder of June the planet is a morning star, and comes to greatest west elongation on June 27th. It then rises rather more than an hour before sunrise, and may be seen on clear mornings shortly before sunrise.

Venus is an evening star, and sets rather more than three hours after the Sun until the latter part of June, when the interval begins to shorten up a little. The planet continually increases its apparent distance from the Sun throughout the period, but its motion eastward along the ecliptic carries it to a region of smaller declination than that of the Sun, and this, toward the close of the period, more than counterbalances the gain in distance as far as it affects the interval between the setting of the Sun and the planet. *Venus* will reach its greatest distance from the Sun early in July.

Mars passed opposition with the Sun on March 28th, and is now beginning to increase its distance from the Earth. On May 1st it sets about 3:30 A. M., on June 1st at 1:30, and at a little before midnight on July 1st. It is therefore still in fine position for evening observation. At the beginning of May it is in the eastern part of the constellation *Leo,* not far from *Denebola,* and is slowly retrograding. This westward motion is small,—only about as much as the Moon's apparent diameter, —and continues until May 10th. The planet then resumes its eastward motion, slowly at first, but by the end of June it will be about 13° east and south of its position on May 10th. In going eastward it will follow a path a little to the south of that pursued in its westward progress, and at the end of June it will be about 4° south of the position it occupied at the end of March. The path of the planet as seen from the Sun crosses the Earth's orbit-plane on June 24th, and the variation of distance from the ecliptic is most strongly marked at this time of node passage. This accounts for the fact noted above that the westward path is so far south of the eastward. The distance of the planet from the Earth in millions of miles varies from 66, on May 1st, to 84 on June 1st, and 104 on July 1st. On June 15th it is at about the same distance from the Earth as the Earth's mean distance from the Sun. The planet will still be very bright, but at the end of June its brightness will be only about one third of that at opposition.

Jupiter is a morning star, but it rises earlier, at 3 A. M. on May 1st, at 1 A. M. on June 1st, and shortly after 11 P. M. on July 1st. It is in the constellation *Pisces,* and moves about 7° eastward and 3° northward, the greater part of the distance being traversed in May. Toward the end of June the motion becomes much more slow, and it will cease about the middle of July.

Saturn rises shortly after 1 A. M. on May 1st, at about 11:20 P. M. on June 1st, and at about 9:16 P. M. on July 1st. It is therefore gradually getting to a position for evening observation. It is in the constellation *Capricorn,* and moves slowly eastward until May 20th. It then begins to retrograde, so that its position at the end of June is about 1° west of the position at the beginning of May. As seen in the telescope, the rings are not as widely open as they were a year ago, the ratio of minor to major axis being less than one third.

Uranus comes to opposition with the Sun on June 15th, and is therefore, during that month, above the horizon nearly all night. It is still in the southern extension of *Ophiuchus* between *Sagittarius* and *Scorpio,* and moves about 2° westward during May and June. Unfortunately there is no bright star near it to afford an easy means of identification.

Neptune, too faint to be seen except with a good telescope, is in the western sky in the evening during May, and reaches conjunction with the Sun on June 23d. On May 15th *Venus* passes it 3° to the north.

(FORTY-THIRD) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to M. MICHEL GIACOBINI, astronomer, Nice Observatory, France, for his discovery of an unexpected comet on December 2, 1902.

The Committee on the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
WM. M. PIERSON.

(FORTY-FOURTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to M. MICHEL GIACOBINI, astronomer, Nice Observatory, France, for his discovery of an unexpected comet on January 15, 1903.

The Committee on the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
WM. M. PIERSON.

NOTICES FROM THE LICK OBSERVATORY.[*]

PREPARED BY MEMBERS OF THE STAFF.

THE ORBIT OF ε *HYDRÆ* AB.

It has been known almost from the time of its discovery by SCHIAPARELLI in 1888 that the close double star known as AB of ε *Hydræ* is a binary system in rapid motion. Measures made by BURNHAM with the 36-inch telescope in the years 1888 to 1892 showed an increase in angle of 40° in the four years. Later observations at Greenwich and, since 1898, at the Lick Observatory, gave evidence that the rate of motion was increasing, the angular change in the twelve years from discovery to 1900 amounting to 150°. But this arc was not sufficient to warrant any conclusions as to the form of the orbit, or even as to the approximate period of revolution.

In 1901 I examined this star with the 36-inch on several nights, but could see no measurable elongation. But on November 15, 1902, I found no difficulty in measuring the pair. The disks of the two components were distinctly separated, and one was sensibly smaller than the other, so that there was no doubt about the quadrant. The smaller star was in the second quadrant, as it had been at the time of discovery in 1888, and had described an arc of 200° in the three years since my measures in 1900. This result was confirmed by two measures secured in February and March of this year.

The mean of SCHIAPARELLI's measures in 1888, as given by BURNHAM,[†] is:—

1888.28	142°.0	0″.21	6^{n}

and my recent measures are:—

1902.873	126°.6	0″.17
1903.139	132 .8	0 .21
.177	136 .9	0 .18
1903.06	132°.1	0″.19

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[*] Lick Astronomical Department of the University of California.

[†] *Publications of the Lick Observatory*, Vol. II, p. 68.

Plotting these measures and those made in the intervening years, as given in Table I, I found it possible to represent them satisfactorily by an ellipse, from which, by graphical methods, I derived the following set of elements:—

$$\begin{array}{llll} T = & 1901.1 & \Omega = & 109^{\circ}.5 \\ P = & 15.7 \text{ years} & i = & 35\ .5 \\ e = & 0.685 & \lambda = & 264\ .7 \\ a = & 0''.24 & n = & +\ 22\ .293 \end{array}$$

These results are considered as approximate only. When further observations have been secured, some of the elements will probably require considerable correction; but, as will be seen from Table I, the observations so far published are represented satisfactorily. The two components of the system differ fully two magnitudes in brightness, and their maximum apparent separation is only 0″.25. It is therefore a difficult pair to measure, even with the most powerful telescopes.

There is a third star about 3″ distant which with the close pair forms the double star Σ 1273. The angular motion of C about the bright star has amounted to about 38° since 1830, without material change in the distance. It is thus evident that we have here a ternary system.

Still further interest attaches to this star from the fact that spectrographic observations show that its velocity in the line of sight is variable.*

At present it is not possible to say what the period of the spectroscopic binary is, but it is comparatively a long one. It is interesting to note that the plates showing the maximum velocity (+43 kilometers) were taken when the visual binary was near the line of nodes; while the plate showing the minimum velocity (+28 kilometers) was taken after the visual binary had described an arc of about 180° and was again near the line of nodes. This may mean that the visual and spectroscopic binaries are identical, but further evidence is needed to determine this question with certainty.

The table that follows gives the data on which my orbit is based, and shows the agreement between the computed and observed places. It includes all complete measures that I have been able to find, except those made at Greenwich in 1901. These measures place the smaller star in the fourth quadrant instead of the first, and hence have residuals exceeding 90°.

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* See Lick Observatory Bulletin No. 4, and *Publications* A. S. P., Vol. XIII, p. 164.

TABLE I.

Date.	θ_o	θ_c	ρ_o	ρ_c	$\Delta\theta$(o−c)	$\Delta\rho$(o−c)	Observer.	n
1888.28	142°.0	145°.7	0″.21	0″.23	— 3°.7	— 0″.02	Schiaparelli	6
1888.98	154 .4	153 .0	0 .26	0 .24	+ 1 .4	+ 0 .02	Burnham	2
1890.92	170 .0	170 .8	0 .19	0 .24	— 0 .8	— 0 .05	Burnham	2
1892.18	179 .6	182 .3	0 .21	0 .24	— 2 .7	— 0 .03	Burnham	2
1896.21	212 .0	223 .3	0 .22	0 .22	— 11 .3	± 0 .00	Lewis........	3
1898.14	250 .7	246 .5	0 .18	0 .20	+ 4 .2	— 0 .02	Aitken	1
1899.15	261 .3	261 .3	0 .22	0 .18	± 0 .0	+ 0 .04	Aitken	3
1899.23	263 .5	262 .6	0 .21	0 .18	+ 0 .9	+ 0 .03	Lewis........	4
1899.92	274 .8	276 .2	0 .18	0 .15	— 1 .4	+ 0 .03	Aitken	1
1900.18	293 .4	283 .1	0 .13	0 .13	+ 10 .3	± 0. 00	Aitken	3
1900.24	267 .2	284 .9	0 .20	0 .13	— 17 .7	+ 0 .07	Lewis........	1
1903 06	132 .1	129 .9	0 .19	0 .20	+ 2 .2	— 0 .01	Aitken	3

March 14, 1903. R. G. Aitken.

THE PRESSURE OF LIGHT AND HEAT AND THE EXPERIMENTAL PRODUCTION OF AN APPEARANCE RESEMBLING THE TAIL OF A COMET.

At the recent meeting of the American Physical Society in Washington, a paper* was presented by Professor E. F. Nichols and G. F. Hull giving the final results of their experiments upon the pressure of heat and light. With the improvements in the apparatus suggested by their early trials, very accurate results have been obtained. The observed pressures agreed *within one per cent* of those computed from theory.

The effect of wave-lengths on the pressure was tested. The pressure was found to be independent of the wave-length and to depend only upon the energy of the radiations. This is in accordance with the theory.

A very interesting application of this pressure effect was made by the investigators in the production of an appearance resembling a comet's tail. A powder consisting of a mixture of emery and puff-ball spores was placed in a vacuum-tube somewhat resembling an hour-glass. The exhaustion of the tube was made as perfect as possible, and especial care was taken to get rid of any mercury vapor. When the powder was poured from one portion of the tube to the other and an arc-light directed upon it at the same time, the lighter portions of the powder were repelled, producing an appearance closely resembling the tail of a comet. The effect was comparable with what was to be expected from the energy observed. The authors considered it possible that the phenomena might be produced in part by other causes. In any event, the experiment reproduced with great accuracy the appearances observed in the tails of comets.

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* "Pressure Due to Radiation." In the account of the meeting in *Science* of January 30, 1903.

This work of NICHOLS and HULL points the way to other investigations which should throw much light on the vexed question of the constitution of the comets. C. D. P.

NOTES ON THE THREE COMETS NOW VISIBLE.

Comet a 1903: The telegram announcing the discovery of a new comet by M. GIACOBINI at Nice was received at the Lick Observatory on January 20th, but continuous stormy weather prevented observations here until the evening of January 29th. As seen with the 12-inch telescope on that date, the comet appeared to be about as bright as a ninth-magnitude star. It was small, nearly round, and with only a feeble condensation. During the month of February the comet grew steadily brighter and larger, and the condensation in the coma became more sharply defined, appearing at the time of the last obsrvation as a bright disk about 2″ or 3″ in diameter. On February 15th, a faint straight tail was visible to a distance of about 5′ in the north-following quadrant. This has grown brighter and longer, being traced to a distance of more than one degree in position-angle 47° on February 25th. When last seen the comet as a whole was as bright as a 6.5-magnitude star.

Comet d 1902: Observations secured here during February show that this comet is following very closely the orbit given in No. 88 of these *Publications* (p. 27). The residuals at the date of my last observations (February 28th) were only $-0^s.6$ and $+9''$. The comet's appearance has changed very little, though it is perhaps fainter than at first. It is still measurable with the 12-inch telescope, and can probably be followed with large telescopes for a month or two more. With one exception its perihelion distance is greater than that of any other comet so far found.

Comet b 1902: PERRINE's comet was last observed here before its perihelion passage on November 17, 1902. After passing the Sun the comet was visible only to observers in the southern hemisphere until late in January, 1903. On the 29th of January, I found the comet close to the place predicted by STRÖMGREN's ephemeris, the observed data being:—

$$\text{Jan. 29, } 12^h\ 57^m\ 38^s \text{ Mt. Ham. M. T. } \alpha = 9^h\ 5^m\ 53^s.99$$
$$\delta = -41^\circ\ 0'\ 55''.7$$

Since then the comet has moved rapidly north and west, passing close to *Sirius* in the latter part of February. On February 28th it was still visible in the 3-inch finder, and the 36-inch showed a faint nucleus.

Stormy weather has prevented observations of any of these comets since February 28th.

March 16, 1903. R. G. AITKEN.

ASTRONOMICAL TELEGRAMS.

(Translations.)

CAMBRIDGE, MASS., Jan. 20, 1903.

To Lick Observatory: (Received 8:30 A. M.)

A comet was discovered by GIACOBINI at Nice on January 15th. It was observed at Nice on January 19.2498 G. M. T., in R. A. $22^h\ 57^m\ 48^s.0$; Decl. $+2^\circ\ 17'\ 36''$. The daily motion is east 17′, north 12′. (Signed) E. C. PICKERING.

BOSTON, MASS., Jan. 22, 1903.

To Lick Observatory: (Received 8:30 A. M.)

Comet *a* 1903 (GIACOBINI) was observed by DINWIDDIE at Washington, on January 21 4915 G. M. T., in R. A. $23^h\ 0^m\ 6^s.5$; Decl. $+2^\circ\ 47'\ 46''$. (Signed) JOHN RITCHIE, JR.

CAMBRIDGE, MASS., Jan. 26, 1903.

To Lick Observatory: (Received 10 A. M.)

Kiel cables the following elements and ephemeris of Comet *a* 1903:—

$$T = 1903,\ \text{March } 24.84\ \text{G. M. T.}$$

$$\left.\begin{array}{rrr} \omega = & 133^\circ & 37' \\ \Omega = & 2 & 32 \\ i = & 30 & 30 \end{array}\right\} 1903.0$$

$$\text{nat. } q = 0.4085$$

Brightness on Jan. 25 = 1.46, on Feb. 6 = 2.64.

(Signed) E. C. PICKERING.

[The ephemeris at 4-day intervals from January 25th to February 6th is here omitted.]

CAMBRIDGE, MASS., Jan. 26, 1903.

To Lick Observatory: (Received 1 P. M.)

SEARES telegraphs that he observed Comet Giacobini on January 25.5643 G. M. T., in R. A. $23^h\ 4^m\ 38^s.3$; Decl. $+3^\circ\ 48'\ 16''$. (Signed) E. C. PICKERING.

REPORTS OF OBSERVATORIES.

ASTROPHYSICAL OBSERVATORY OF THE SMITHSONIAN INSTITUTION.*

During the past year the acquisitions of property have been as follows: *Apparatus.*—Astronomical and physical apparatus has been purchased at an expenditure of $2,000. *Library and Records.*—The library has been enlarged by the addition of periodicals and books of reference at an expenditure of $200. Books and periodicals have been bound at an expenditure of $250. Total for library, $450.

The Solar-energy Spectrum.—The early work of this Observatory described in Volume I of its Annals was chiefly concerned with the minute absorption bands in the intra-red solar spectrum; automatic prismatic energy curves were made by the aid of the bolographic process, and such inflections of these curves as were found not accidental in their origin corresponded to the so-called Fraunhofer lines of the visible spectrum. Less attention was paid to the whole height of these curves at their various parts than to these numerous small variations in height.

The Absorption of the Atmosphere and of the Solar Envelope.—This present year care has been taken to obtain energy curves whose heights shall be comparable. It was the purpose of this work to study the general absorption of the sun's envelope, the general absorption of the earth's atmosphere, and the changes in the selective absorption of water vapor in the latter. It is the further object toward which these studies tend to see if the Sun is constant or variable in its output of radiation. While the results of the past year indicate possibility of considerable ultimate success in this final object, it may probably prove that the situation of this Observatory is unsuitable to the most exact studies of this kind, owing to the great and variable absorption of the air column above it, as well, of course, as to the ground tremors inherent in its present site, surrounded by the traffic of city streets. It seems certain, however, that valuable contributions to the methods of study to be adopted in work at more favorably situated stations, and to the knowledge of terrestrial absorption, can be made here.

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* Condensed, with permission, from "Report of the Work of the Astrophysical Observatory for the year ending June 30, 1902, by C. G. Abbott, *Aid Acting in Charge*."

Absorption of the Atmosphere and Selective Absorption of Water Vapor.—Since January 20th all favorable opportunities have been used to take quick-speed energy curves. These have been made with quite different altitudes of the Sun. Sometimes as many as 15 have been taken in one day, and 160 were secured between January 20th and July 1st. These curves are studied from two points of view: first, as regards the variation in height for single wave-lengths with different altitudes of the Sun; second, as regards the variation in area and especially the areas of the great regions of water-vapor absorption. The first kind of examination leads to the determination of the general absorption of the air, the second to fixing the variations in amount of the solar radiation and of the special selective absorption of water vapor.

To illustrate the first method of study, let us suppose several energy curves to have been taken in a single clear day, during which the barometer height was (B), and let (B_0) be the standard barometric height, generally taken as 76^{cm}. From the altitudes of the Sun as computed from the hour angles and declination, the air mass (m) is determined. This quantity represents the ratio which the mass of air traversed by the solar beam bears to that mass of air which would be traversed if the Sun was directly overhead. If we suppose (e) to represent the amount of radiant energy per square centimeter of a certain wave-length which reaches the Earth's surface, and (e_0) the amount prior to absorption by the Earth's atmosphere, and let (a) be the proportion transmitted per unit air mass, then by the well-known formula of BOUGUER:—

$$e = e_0 a^{m \frac{B}{B_0}}$$

But since the height (d) of the bolographic energy curve at the wave-length in question is proportional to (e), we may write:

$$d = ke = ke_0 a^{m \frac{B}{B_0}}$$

where (k) is an instrumental factor connected with the width of the slit, the absorption of the optical surfaces, the quality of the bolometer, and the sensitiveness of the galvanometer. We may assume (e_0) and (k) to be constant for the short space of time occupied by one day's observations. We then obtain the following equation:—

$$\log (d) = m \frac{B}{B_0} \log (a) + \log (ke_0)$$

of which the last term is constant. This equation is in the form of the equation of a straight line, so that if we make a plot in which heights are proportional to logarithms of (d), and horizontal distances to values of ($m \frac{B}{B_0}$), the various observations should determine a straight line the tangent of whose inclination is the quantity log. (a). The procedure has been followed with many of the energy curves already taken.

Absorption of the Solar Envelope.—The experiments on the absorption of the solar envelope briefly mentioned in last year's report were continued as far as practicable with the apparatus available.

Personal-equation Machine.—You* have placed at the Observatory for trial an instrument of your own design intended to eliminate the so-called personal equation of individual observers in transit observations. The principle of this instrument consists in substituting a judgment of the place where a sudden phenomenon occurred for the time when it occurred. To use an illustration which you have already employed, in case the dark field in which only the star is seen moving were illuminated every two seconds by a self-recording flash which showed the central wire, and if by pure accident the star was caught in an exact bisection when the flash came—an accident against which the chances are perhaps more than a hundred to one—it is evident that in this rare and improbable event there would be no personal equation to allow for, if the time of flash within two seconds were noted by the observer. Now, the object of the following mechanism may be said to be to make this accident happen every time.

This being understood, as first tried with the apparatus which you furnished, the design was to illuminate the cross-wires of the transit instrument by automatically recorded electric flashes occurring at regular intervals equal to the time elapsing between passages of the star across successive wires. An adjustable mechanism allowed the observer to hasten or defer the whole system of flashes until by successive adjustments he caught the exact instant when the star was bisected by the dark wire in the instantaneously bright field. Several such adjustments could be made during a single star transit across the numerous wires of the tally, and immediately after each satisfactory bisection a signal was made on the chronograph by a key in the hand of the observer, so that only such recorded flashes as were thus distinguished were used in determining the time of transit.

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* This report is addressed to Professor S. P. LANGLEY, Secretary of the Smithsonian Institution.

In order to test the value of this instrument an artificial star was caused to move through the field at a rate about equal to that of a real equatorial star. This star was moved by a screw and clockwork of great accuracy, and always through the same portion of the screw. It was also provided that when the star was exactly bisected by the middle wire an electrical contact was broken, so that the star recorded its own transit upon the chronograph. The adjustment of the contact for this bisection was made at leisure with the star stationary, and was therefore not subject to the personal error of transit observations. Accordingly, after determining all the wire intervals, it was entirely easy to measure the personal equation of the observer, whether he used the personal-equation machine or the ordinary method, merely by comparing his observed time of transit with that recorded by the star itself. Upon trial it was found that the personal equation of the several observers was not wholly prevented by employing the machine in the manner described; that is, by bisections judged during instantaneous flashes. The writer, for example, observed about 0.12 second too early by both methods.

It seemed probable that the observer was still biased in his judgment by watching the march of the star through the field across the very faintly showing wires, which are always to be made out by the stray light of the star and sky, even though there is no illumination by the flash. Accordingly it seemed to promise success to alter the arrangement so that the star would be hidden except at the instants corresponding to those when the flash had formerly appeared, and to steadily illuminate the field as is usual in transit instruments. In the test this was easier than in actual practice, for the artificial star itself could be obscured by a shutter immediately in front of it, which could be removed instantaneously by the electric signal from the personal-equation machine. The same thing could, however, be done at the focal plane of the telescope in real use.

Upon trial this device justified all hopes. Three observers whose habit is to observe, one too early, one too late, and the other very close to the true time, were found all to observe as close to the truth as the accidental errors would admit, which in the case of the 3-foot focus transit instrument employed was generally within 0.03 second. In other words, personal equation seems to be wholly eliminated by this procedure. The general design may be applied without great expense to any outfit of transit and chronograph.

Experiments on "Boiling" of the Image.—I add a few words, partly in anticipation, in reference to your newly-introduced device for preventing the well-known effect of "boiling" of the telescopic image, a difficulty due to the Earth's atmosphere and which has existed always and everywhere, and which has seemed until lately so insurmountable that it has not even been thought of as subject to correction. The device that you have suggested consists essentially not in keeping the air still within and without the telescope tube, but in violently agitating it over as great a range as possible. For this purpose, under your instructions and with the object of rehearsing on a small scale what, if the device is successful, will be later tried on a large one, a silvered-glass mirror of five inches diameter and forty feet focus has been set up in a tube with several concentric walls, so as to leave the interior air as still as possible. In preliminary experiments the air, in spite of these precautions in the installation, gave such "boiling" of the image as to seriously prejudice the definition, and this, although the forty-foot tube had no less than three walls, being seven inches in interior diameter and fifteen inches in exterior diameter, and inclosing the beam all the way from a second plane mirror near the cœlostat to the concave mirror and thence to the focus. Though this tube containing the stillest air of the most uniform temperature was sheltered throughout by a canvas tent, the "boiling" was but a little diminished. Nothing was gained by diminishing the aperture of the several mirrors down to one inch in diameter, and all this was only what had been anticipated from the ordinary experience of astronomers. A twelve-inch blower run by an electric motor was now caused to exhaust air from the inner tube at a half-dozen points along the tube, and to force air in at other points alternate with these, so as thus violently to disturb or "churn" the air by forcing a vigorous circulation of it along the whole path of the beam from the cœlostat to the solar image. This unquestionably reduced the "boiling." An artificial star was now provided at the focal plane, the plane mirror near the cœlostat was placed at right angles to the tube, and thus the concave mirror, acting as both collimator and objective, brought the star-image to focus at the star itself. Here it was examined with an eye-piece. With still air the definition was often very poor. The image assumed very variable shapes, with wings or streamers; and being also colored by diffraction effects, reminded one of a kaleidoscope field. On starting the blower the definition immediately became sharp. Violently stirring the air in the tube, therefore, eliminates the "boiling" within the tube and (paradoxically) produces a still image. As before said, the solar image was clearly improved by the stirring; but further improvement was still to be desired. Accordingly a tin tube forty-four feet long, with two walls of eleven inches interior diameter and sixteen inches exterior diameter, was provided and arranged to point toward the Sun, so that the beam passed down through it before reaching the mirror system. This tube was connected to the blower exactly like the horizontal one, and both could be stirred at once. There was a very marked "boiling" before starting the blower. This nearly disappeared while the blower was running. One observer estimated the "boiling" as four-fifths overcome; another thought little more than a quarter remained, and all were unanimous that what was left was very little prejudicial to the definition. This last result is so surprising that I feel constrained to add that the experiments so far are not exhaustive, having been carried on but a short time, and without that solidity of piers which would allow of exact estimate or photographic determination of the "boiling" of the solar image before and during agitation of the air in the tube, as distinguished from mechanical jarring. Further experiments are in progress. That agitation is of very great advantage to diminish "boiling" there is no question, but the exact measure of the advantage for all circumstances of bad seeing requires further study. Incidentally, the air blast has the added advantage of keeping the mirrors at uniform temperature. This and the abolishment of "boiling" in the tube are found to prevent those vexatious changes of focus so common in solar work.

Radiation of the Cuban Firefly.—In continuance of your observations on the cheapest form of light, two specimens of the Cuban firefly were loaned by the Agricultural Department. The radiation of the thoracic-light regions of these insects was briefly studied by the aid of the bolometer and photometer. A comparison of the light and heat of the standard sperm candle with that of the firefly showed the latter to be more than 10,000 times more economical as a source of light.

Personnel.—The observing-staff has been unchanged with the following exceptions: Dr. C. E. MENDENHALL was employed as temporary assistant up to August 3, 1901, and Dr. N. E. GILBERT as temporary assistant, beginning June 16, 1902.

LEANDER McCORMICK OBSERVATORY OF THE UNIVERSITY OF VIRGINIA.

ORMOND STONE, DIRECTOR

Among the recent researches undertaken at the Leander McCormick Observatory, is an investigation of the standards of faint stellar magnitudes in co-operation with the Harvard, Yerkes, and Lick observatories, to be followed by a study of the more important long-period variables. The former work was done principally by Mr. H. D. CURTISS (Ph. D., 1902), now of the Lick Observatory; in the latter Professor STONE is assisted by Mr. PADDOCK, one of his present students.

LOWELL OBSERVATORY, FLAGSTAFF, A. T.

A little more than a year ago, an efficient modern spectrograph, designed and built by JOHN A. BRASHEAR, of Allegheny, Pa., was added to the equipment of the observatory. The attachment of this instrument to the twenty-four-inch refractor necessitated the enlargement of the dome. This work was begun in December, 1901, and completed in March of the following year. During this period, when possible, the telescope was used in measuring star-disks.

Since that time, after the completion of the adjustments of the spectroscope, the twenty-four-inch refractor was devoted to the photographing of stellar spectra for motion in the line of sight, until August. Since then, the time has been divided between stellar and planetary work. Successful spectrograms have been obtained from *Uranus, Jupiter, Saturn, Mars, Venus,* and the asteroid *Vesta.*

During the last part of the year considerable time has been given to visual observation of planets, chiefly *Mars.*

January 31, 1903. V. M. Slipher, *for Observatory.*

THE CHAMBERLIN OBSERVATORY OF THE UNIVERSITY OF DENVER.

During the first six months of 1902 no observations were made with the twenty-inch telescope, because the time of the observers was otherwise filled. But some minor repairs and alterations were made in the instrument.

In July Dr. Charles J. Ling began a search for *Eros,* which culminated in its visual rediscovery early in August. From September on observations of comets and of *Eros* have been made.

February 7, 1903. H. A. Howe, *Director.*

GOODSELL OBSERVATORY OF CARLETON COLLEGE, NORTHFIELD, MINNESOTA.

The research work of this observatory is at present devoted almost exclusively to solar and celestial photography. A few micrometric observations of double stars and comets are made with the sixteen-inch refractor on nights unsuitable for photography. Daily photographs of the Sun have been taken whenever possible since 1889. The approximate measures of the photographs taken from 1889 to 1893 were published last summer in *Publication* No. 3 of Goodsell Observatory.

There are on hand something like 1,200 solar photographs taken since 1893, which have not been measured because of the lack of the necessary funds for assistance, the time of the two professors being fully occupied with their duties in the instruction of the college classes, and the work of editing "Popular Astronomy."

So far as his strength would permit, Professor Wilson has given his time on the moonless clear nights to long-exposure photographs with the eight-inch Clark refractor, the six-inch Brashear star-camera, and the 2½-inch Darlot camera. These three instruments are on the same mounting and are guided by means of a five-inch telescope fastened rigidly to the eight-inch and of the same focal length with it. Most of the photographs have been of four or eight hours' exposure, the latter requiring two nights. The most successful one of the *Andromeda Nebula* received twelve hours' exposure, requiring four nights' work. The longest attempted exposure with the eight-inch was one of seventeen hours on the *Pleiades,* which failed because of imperfect backing of the plate, but the details shown on parts of the plate showed that the limit of useful exposure with this instrument had by no means been reached. With the smaller instruments the exposure has seldom been prolonged beyond eight hours, and that with the 2½-inch lens was usually stopped with one night, its construction being such that there was danger of shifting the plate on inserting the slide. A number of the photographs taken with the cameras indicate the existence of large regions of very faint nebulosity, those covering large portions of the constellations *Orion, Taurus,* and *Scorpio* being the most notable. They are so faint that very careful development is required to bring them out upon the plates, and prints can be made only from intensified copies. They require, too, the most transparent atmosphere.

During the past six months our time for research work has been devoted wholly to the measurement and reduction of the photographs of *Eros* taken during the parallax campaign of the winter 1900-1901. By the aid of a grant of $300 from the Gould Fund and the loan of the Repsold measuring-machine belonging to the University of Minnesota, we were enabled during the summer to measure sixty-six out of the seventy-four *Eros* plates, the others being too defective for measurement. The number of comparison-stars, of the list published in circulars numbers 8 and 9 of the "Conference Astrophotographique Internationale," found upon each plate within the range of good definition, varied from five to ten. Both coordinates were measured, in two opposite positions of the plate. Six plates taken during the week November 7-15th were measured a second time, with a list of comparison-stars furnished by Mr. Arthur R. Hinks, of Cambridge Observatory, England. For these plates the comparison-stars numbered twelve to fourteen each. These measures are to be used by Mr. Hinks in a special determination of the parallax from the measures at many observatories during that one week.

The work of reduction goes on very slowly in connection with our regular duties, but the measures of ten plates have already been reduced provisionally. These ten are rather poorer than the average, but the results obtained show that they were worth measuring.

The probable error of the measurement of a single image of a star on one plate comes out about 0".20, and from the mean of four or five images about 0".12, while the probable error of the center of the plate from all the stars is usually below 0".10. The Declinations, as a rule, come out better than the Right Ascensions, the residuals being only from half to two thirds as great in the former as in the latter. This difference is probably due to the slight elongation of the images in consequence of the imperfect driving of the clock. On the best of the plates the images are perfectly round over two thirds of the diameter of the field,—*i. e.* over a circle with a radius of forty minutes of arc. The probable error of a single measure on these is about 0".11 and that of the center of the plate from all the comparison-stars is from 0".04 to 0".07.

March, 1903. William W. Payne, *Director.*

YERKES OBSERVATORY, WILLIAMS BAY, WIS.

When the Yerkes Observatory was dedicated in October, 1897, its equipment consisted of the forty-inch refractor, with one or two accessories, and the instruments which had formerly belonged to the Kenwood Observatory. It was necessary to supply a complete series of accessory instruments for use with the forty-inch refractor, and a numerous collection of other instruments required for the varied purposes of a large ob

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servatory. As funds were not available for this purpose, it was decided to provide a well-equipped instrument-shop, in which the necessary instruments could be constructed. The considerable time required to bring into effect the plan of investigations prepared when the observatory was under construction has been due in large extent to the necessity of constructing the instruments one by one with the limited means available for the purpose.

At the end of 1901 the equipment was fairly complete, though some of the more important instruments had not been finished. During the year, covered by this report (1902), however, several new investigations requiring special equipment have been undertaken, and the present programme of research represents most of the investigations originally proposed. The further additions which the provision of new funds and the completion of new instruments should render possible during the coming year, will complete the original programme.

Staff.—The staff of the Yerkes Observatory is at present constituted as follows: George E. Hale, Professor of Astrophysics and Director (solar, stellar and laboratory spectroscopy); S. W. Burnham, Professor of Practical Astronomy (double stars); E. E. Barnard, Professor of Practical Astronomy (micrometric observations, stellar photography, etc.); Edwin B. Frost, Professor of Astrophysics (stellar spectroscopy; velocities in the line of sight); G. W. Ritchey, Instructor in Practical Astronomy and Superintendent of Instrument Construction (photography of nebulæ, star-clusters, etc.); Ferdinand Ellerman, Instructor in Astrophysics (solar and stellar spectroscopy, and general photography); Storrs B. Barrett, Secretary and Librarian (solar spectroscopy); Walter S. Adams, Assistant (stellar spectroscopy; velocities in the line of sight) J. A. Parkhurst, Assistant (photometry and stellar spectroscopy); N. A. Kent, Assistant (laboratory spectroscopy); J. A. Johannesen, Instrument Maker; O. F. Romare, Machinist; F. R. Sullivan, Engineer in Charge of 40-inch Telescope and Night Assistant; F. G. Pease, Optician.

Double Stars (Professor Burnham).—Up to the end of 1899 Professor Burnham was engaged in measuring all stars of short period, and others for which observations were lacking, for use in his "General Catalogue of 1290 Double Stars," which appeared in 1900 as Volume I of the *Publications of the Yerkes Observatory.* Since that time he has confined his attention to a carefully selected list of stars, consisting mainly of long-neglected and little-known pairs. Many of these, taken from the catalogues of Sir WILLIAM HERSCHEL, Sir JAMES SOUTH, and other astronomers at the end of the eighteenth and beginning of the nineteenth centuries, have never been observed since that time. The list also includes many pairs recorded in various journals and observatory publications during the last fifty years which have been insufficiently observed or not measured at all. Among the other neglected pairs are those in which the evidence of decided change is of a somewhat doubtful character. These have been reobserved, and the supposed change shown to be real in some instances, but due to errors of observation in others. For special reasons some of the Σ and β stars have been measured, with others from the Astronomische Gesellschaft catalogues. Altogether some 600 of these objects are given in a paper which will appear soon in Volume II of the *Publications of the Yerkes Observatory.* As Professor BURNHAM'S object has been to avoid duplicating work done elsewhere, he has placed no star on the working-list which would be likely to be measured at any other observatory.

General Micrometric Observations (Professor BARNARD). —Professor BARNARD has continued his work on the satellite of *Neptune,* which he has had under observation for several years. He has also obtained several valuable series of measures of the fifth satellite of *Jupiter.* His measures of 61^1 *Cygni,* for the purpose of redetermining its parallax and testing the conclusions of WILSING, were continued during the year and are now in process of reduction. Professor BARNARD'S most extensive investigation with the forty-inch refractor has been a systematic micrometrical survey of between 600 and 700 small stars in the globular clusters *M* 3, *M* 5, *M* 13 and *M* 92. In the course of this work he has compared his measures of a large number of stars in *M* 13 *Herculis* with Professor SCHEINER'S measures of the same stars, made on photographs taken at Potsdam in 1891. The comparison shows that the photographic and visual measures in general agree very closely, though there are a few discordances, amounting to one or more seconds of arc. Apparently these are not due to motion in the stars, but rather to the difficulty of making the photographic measures in the case of defective images. In the period of ten years there does not appear to be any certain proof of motion in any of the stars under observation. In the course of the work on clusters Professor BARNARD has given special attention to some of the variable stars in *M* 5 *Libræ,* for which he has determined accurate periods. In addition to the work here mentioned, Professor BARNARD has done a large amount of miscellaneous work with the forty-inch telescope, including micrometric observations of planetary nebulæ; a few double stars, such as *Procyon;* determinations of the position and focus of *Nova Persei,* etc. The measures of the *Nova* gave no evidence of a parallax. Up to August, 1902, long after the spectrum of the *Nova* had changed to that of a planetary nebula, it was found to have the same focus as that of a neighboring star. The change of focus, which was noted in September, 1902, has been described in the *Astrophysical Journal.*

Velocity of Stars in the Line of Sight (Professor FROST and Mr. ADAMS).—The Bruce spectrograph, which was completed in the instrument-shop of the observatory early in 1902, has given most satisfactory results. None of the difficulties encountered with the old three-prism spectrograph have appeared in the new instrument, and the degree of precision fully equals, if it does not surpass, the highest reached elsewhere. The twelve lunar spectra photographed during the year, for the purpose of testing the adjustment and trustworthiness of the spectrograph, gave a mean difference of 0.2^{km} per second between the observed and the computed radial velocity of the Moon, the largest difference being 0.7^{km} per second. The titanium spark was chiefly used for furnishing the comparison spectrum, but the iron and chromium spark and a helium tube were also employed at times. The principal piece of work during the year was the measurement of the radial velocities of stars having spectra of the *Orion* type. These spectra are not adapted to very accurate measurement, as the lines are comparatively few and are generally hazy and ill-defined. In spite of this fact, the results have proved fairly accordant. The lines commonly present and measured were those due to one or more of the following elements: helium, oxygen, silicon, nitrogen, hydrogen, magnesium. In a paper to appear shortly in the *Publications of the Yerkes Observatory*, the detailed results of the investigation of the radial velocities of twenty stars will appear. The velocities found for these stars, expressed in kilometers per second, are given below:—

γ *Pegasi*	+ 5.4	ε *Can. maj.*	+ 27.2
ζ *Cassiopeiæ*	+ 2.9	η *Leonis*	+ 3.5
ε *Cassiopeiæ*	— 5.9	γ *Corvi*	— 7.0
ζ *Persei*	+ 22.1	τ *Herculis*	— 12.7
β *Orionis*	+ 20.7	ζ *Draconis*	— 14.4
γ *Orionis*	+ 18.0	ι *Herculis*	— 16.4
ε *Orionis*	+ 26.7	67 *Ophiuchi*	— 3.1
ζ *Orionis*	+ 18.3	102 *Herculis*	— 10.8
κ *Orionis*	+ 17.1	η *Lyræ*	— 9.1
β *Can. maj.*	+ 32.6	ε *Delphini*	— 26.2

Many of these stars are near the apex or anti-apex of the Sun's way, and if corrected for the solar motion the resulting absolute radial velocities would be small. In the course of the year six spectroscopic binaries were discovered, and have been made the subject of special investigations. An orbit for one of these binaries, *η Orionis*, has been computed by Mr. ADAMS.

Through Professor FROST'S initiative an important co-operative movement, participated in by the principal observatories engaged in investigations of radial velocity, has been set on foot. This involves the systematic measurement of the radial velocities of certain standard stars, selected with particular reference to their suitability for measurement. The results of this work will give for the first time a reliable means of determining systematic errors in investigations of radial velocity.

The Spectra of Stars of Secchi's Fourth Type (Professor HALE, Mr. ELLERMAN, and Mr. PARKHURST).—An investigation of the spectra of red stars of SECCHI'S fourth type was completed during the year. Some 250 photographs, made with a three-prism spectrograph attached to the forty-inch refractor and the two-foot reflector, ranging in exposure time from a few minutes up to twenty-five hours, were obtained in the course of this research. A special study has been made of eight stars, in whose spectra the wave-lengths of several hundred bright and dark lines have been measured. The bright lines have not been certainly identified, but the dark lines have been found to be due to iron, titanium, and various other substances. They have also served for the determination of the radial velocities of the stars. Low-temperature lines, particularly those of calcium, are very conspicuous in these spectra. In many cases the more conspicuous dark lines seem to correspond with lines which are widened in the spectra of sun-spots, but this cannot be made the basis of any theoretical conclusions before further investigations with higher dispersion have been made.

Solar Observations (Professor HALE, Mr. ELLERMAN, and Mr. BARRETT).—The programme of solar work prepared for the Yerkes Observatory includes systematic investigations along the following lines:—

1. Direct Photography: Daily photographs of the Sun on a scale of seven inches to the solar diameter; large-scale photographs of spots and other regions.

2. Monochromatic Photography: Daily photographs with the spectroheliograph, for systematic study of the form, area, distribution, and motion of the calcium vapor on the disk and in the chromosphere and prominences. Comparative photographs in various bright and dark lines and other special researches.

3. Daily photographs of the spectrum: (*a*) of sun-spots, for the systematic study of the positions and intensities of the widened lines and the bright H and K lines; (*b*) of various regions of the photosphere, for the study of the bright H and K lines and the detection of possible changes in the position or intensity of dark lines; (*c*) a special series of photographs taken at the shortest practicable time intervals, near the sun-spot maximum, in order to register, if possible, such remarkable changes in the reversing layer as were recorded on a single plate taken at Kenwood in 1894.

4. Special researches, radiometric, visual, and photographic, on the spectrum of the reversing layer and the chromosphere with a large solar image and powerful grating spectroscope.

5. Investigations on the solar rotation, determined with the spectroheliograph and by spectrographic observations of the photosphere, spots, chromosphere, and prominences.

6. Radiometric investigations of various kinds.

7. Visual observations to supplement those made photographically.

Through unavoidable delays in the construction of the necessary instruments, some of these investigations are not yet in progress. At present the direct photographs of the Sun are being taken daily with the twelve-inch refractor, which gives a solar image two inches in diameter. In a short time, however, this work will be transferred to the forty-inch telescope, which gives a seven-inch image. The large spectroheliograph constructed for the forty-inch telescope, in spite of its great size and weight, and the special mechanical arrangements required for its operation, has yielded excellent results after a large amount of experimental work. The slits of this instrument are eight inches long, permitting the seven-inch solar image given by the forty-inch telescope to be photographed in monochromatic light. When the construction of the cœlostat reflector had been decided upon, it was thought best to transfer the spectroheliograph from the forty-inch telescope to this instrument. But the delay occasioned by the injury of the latter instrument by fire has caused us to resume the work with the large telescope, and a daily series of photographs is now being secured with the large spectroheliograph. Excellent photographs have been obtained with the remodeled Kenwood grating spectrograph of the widened lines in the spectra of sun-spots, and many of these have been measured. Various special studies have also been made of the spectrum of the chromosphere. The large size of the solar image given by the forty-inch telescope renders it particularly suitable for this work.

Photography of the Moon, Nebulæ, and Star Clusters (Mr. RITCHEY).—Mr. RITCHEY'S successful adaptation of the forty-inch visual refractor for photography by the use of a color-screen and double-slide plate-holder has made it possible for him to obtain many important photographs of the Moon, nebulæ, and star-clusters with the large telescope. When compared with similar photographs taken with the largest photographic refractors, these results appear to surpass in sharpness any previously obtained. The simplicity and cheapness of the color-screen method, and the ease with which it can be applied to existing visual telescopes, will recommend it to those who are not provided with photographic telescopes. In the lack of a measuring-machine, which will be supplied in the immediate future, it has not been possible to make a careful study of the distortion of the negatives produced by the color-screen. There seems to be no doubt, however, that this is of such a character that it can easily be allowed for.

The excellent results obtained by Mr. RITCHEY in photographing the nebula surrounding *Nova Persei*, as well as various other nebulæ and star-clusters, with the two-foot reflector recently constructed in the observatory shops, have demonstrated that work of great importance can be done with a properly constructed reflecting telescope of comparatively small aperture. There can be no doubt that the development of reflecting telescopes during the last fifty years has been greatly retarded by the insufficient attention given to the mechanical design and construction of the mountings. The excellent photographs obtained with the Crossley reflector by Professor KEELER and Mr. PERRINE indicate that with sufficient skill and persistence some of the older instruments may yield good results, but with suitably designed mountings most of the difficulties experienced in this work disappear. The remarkable photographic efficiency of the reflector is shown by the fact that stars at the limit of vision with the forty-inch refractor can be photographed with the two-foot reflector in forty minutes. With longer exposures innumerable stars, one or perhaps two magnitudes fainter than those at the limit of the forty-inch, can be photographed. As there can be no doubt that larger reflectors, when used under good atmospheric conditions, will produce proportionately better results, it is hoped that means may soon be found to mount the five-foot mirror made by Mr. RITCHEY in the optical shop of the Yerkes Observatory.

Photometry (Mr. PARKHURST).—For some time past the Yerkes Observatory has been co-operating with the Harvard, McCormick, and Lick observatories in the work of determining standards for faint stellar magnitudes with a wedge photometer supplied by the Rumford Committee of the American Academy of Arts and Sciences. Mr. PARKHURST has made a careful series of determinations of the wedge constant by the method of standard stars and also with a wheel photometer. The wedge photometer has been systematically used with a six-inch reflector and with the twelve-inch and forty-inch refractors. In addition to the observations of faint standards made with the forty-inch telescope, which have been fewer than was hoped on account of the unusually bad weather and the small amount of time that could be spared from other investigations, Mr.

PARKHURST has photographed many of the fields containing the standards with the two-foot reflector. Paper prints of these show stars down to the seventeenth magnitude or fainter, and render the identification of the faint standards certain, a work equally important with the photometric measures themselves. In addition to this photometric work, Mr. PARKHURST has continued his observations of variable stars, giving special attention to those which are exceedingly faint at minimum.

Spectroscopic Laboratory (Professor HALE and Dr. KENT). —During the year the equipment of the spectroscopic laboratory has been greatly increased, and now includes a six-inch concave grating spectroscope of 21½ feet focal length, with smaller concave gratings for special purposes; a 3 K. W. 110-volt alternating dynamo, presented by Dr. GEORGE S. ISHAM; a 1 K. W. transformer, giving 15,000 or 30,000 volts; various induction coils, including a high-frequency coil presented by Mr. JAMES LYMAN; a large condenser, volt-, watt-, and ammeters, and other apparatus presented by Dr. ISHAM; and various miscellaneous instruments. The various light sources, including the arc in air, rotating arc in liquids, spark in air at various pressures, spark in liquids, etc., are arranged on the circumference of a circular table, at the center of which is a plane mirror. By means of this mirror the light from any source can be reflected to a large concave mirror, which forms an image of the source on the slit of the concave grating spectroscope in the adjoining room. To pass from one source to another it is only necessary to rotate the plane mirror. This arrangement has proved very convenient in practice, and is believed to eliminate the danger of such displacements of lines as sometimes occur when an adjustable image lens is used in front of the slit.

The principal work of the spectroscopic laboratory during the year has been an investigation on the spark spectra of iron and other metals in liquids and in air at high pressures, in connection with solar and stellar spectra. By changing the constants of the discharge circuit, or by varying the pressure of the air in which the spark is observed, it has been found possible to pass by successive steps from a bright line spectrum to one consisting almost wholly of dark lines in the ultra-violet. The reversals appear first in the ultra-violet and gradually advance toward the less refrangible region, thus reproducing the effect observed by Professor CAMPBELL in certain stars, whose spectra contain dark hydrogen lines in the ultra-violet and bright ones in the less refrangible region. A careful study has been made of the displacements of the lines which accompany the changes of the absorption phenomena, and these are being discussed with reference to their bearing on the spectra of temporary stars.

Cœlostat Reflecting Telescope.—In view of the excellent photographs of the corona obtained by Professor BARNARD and Mr. RITCHEY at the eclipse of May 28, 1900, with the aid of a cœlostat constructed in the observatory shops, it was decided to build a much larger cœlostat, to be used with concave mirrors of various apertures and focal lengths for astronomical photography and for spectroscopic observations requiring the use of large-grating spectroscopes mounted under laboratory conditions. The cœlostat, which had a mirror of thirty inches aperture, was completed with the aid of grants from the Rumford and Draper Funds in the autumn of 1902. Light from the cœlostat mirror was reflected to a second plane mirror of twenty-four inches aperture, which sent the rays in a southwesterly direction to a concave mirror of sixty-two feet focal length. This mirror returned the rays and formed the image near the cœlostat. All parts of the apparatus, including the mirrors, were made in the observatory shops under the direction of Mr. RITCHEY. For direct photography a double-slide plate-holder was to be used. For photographic work on the spectra of some of the brightest stars there was provided a concave-grating spectrograph, having a six-inch grating ruled by Mr. JEWELL on Professor ROWLAND's engine for this research, used in conjunction with a collimating lens of five inches aperture and thirteen feet focal length. This was mounted on solid piers in a double-walled room, arranged with automatic apparatus to maintain a constant temperature. When in process of adjustment, the insulation of the wires connected with the comparison-spark apparatus broke down, setting fire to the walls of the room. A high wind was blowing, and it was impossible to extinguish the flames, which destroyed the spectrograph house and the building containing the cœlostat and mirrors. The twenty-four-inch plane mirror was saved, and most of the heavier parts of the apparatus were not injured. The reconstruction of the instruments is going on rapidly in the Observatory shops, and it is hoped that they may be in use during the summer of 1903.

Bruce Photographic Telescope.—A ten-inch photographic objective of the portrait-lens type, having a focal length of fifty inches, was completed by BRASHEAR and thoroughly tested by Professor BARNARD during the year. There has been great delay in securing a suitable objective, on account of the difficulty of obtaining a sufficiently large field. With the present lens, used with a plane plate, it is expected that good definition will be obtained over a field about 9° in diameter. This will be extended to 12° by the use of a curved plate. WARNER & SWASEY have made designs for the mounting, and it is hoped that the instrument will be ready for use in the summer of 1903.

Publications.—Volume II of the *Publications of the Yerkes Observatory,* containing papers by Messrs. BURNHAM, BARNARD, MOULTON, FROST, and ADAMS; HALE, ELLERMAN, and PARKHURST; RITCHEY; and LAVES, will be published within a few months. Observatory bulletins are now issued rarely, and are used only to provide for the publication of information which does not naturally find a place in other channels. The usual number of scientific papers have been communicated by members of the staff to the various journals.

Grant from the Carnegie Institution.—The Carnegie Institution has appropriated $4,000 to be expended by the Director of the Yerkes Observatory for various investigations to be undertaken during the year 1903. These will include:—

1. A photographic investigation of stellar parallaxes, to be made by Dr. FRANK SCHLESINGER, now in charge of the International Latitude Observatory at Ukiah, California. Dr. SCHLESINGER will commence his work at the Yerkes Observatory in May.

2. Special photometric observations, by Mr. J. A. PARKHURST. Hitherto Mr. PARKHURST has devoted the greater part of his time to the measurement and reduction of stellar spectra, but hereafter his entire attention will be given to photometric work and related investigations on variable stars.

3. A detailed study of the photographs of the Sun, number-

ing over 3,000, taken during the years 1891-1896 with the spectroheliograph of the Kenwood Observatory. Mr. Philip Fox, formerly Instructor in Physics at Dartmouth College, is assisting in this work.

4. Various special investigations, which will probably include stellar and solar spectroscopic work with the cœlostat reflector. George E. Hale, *Director.*

LICK OBSERVATORY, MOUNT HAMILTON, CALIFORNIA.*

The Lick Observatory suffered an irreparable loss in the untimely death on August 12, 1900, of Dr. James Edward Keeler, Director from June 1, 1898. The announcement of his death came as a great shock to his colleagues and friends widespread, who had seen before him a career of rarest promise. The elements of his successes were simple, and plainly in view. His openness and honesty of character, his willingness and quickness to see all points of view, his strong appreciation of the humorous as well as the serious, and, above all, his abounding good sense,—these traits made his companionship delightful and charming. His published papers have a completeness, a ripeness, and a finish rarely seen.

Our appreciation of his worth has not grown dim with time.

Dr. Keeler's last observations were made with the Crossley reflector in the hope of recording the image of a ninth satellite of *Saturn*, reported to exist by Professor W. H. Pickering. No trace of the satellite was detected, but the plate of June 28, 1900, led to the discovery of an asteroid, *1900 GA*,—probably the faintest one known.

While the Observatory is pre-eminently an observation-station, yet it is not so in a narrow sense. Success in observational work demands, (1) knowledge of what has been done by others; (2) knowledge of pending problems, and of the most promising methods for their solution; (3) knowledge as to how observations will be used, and when they should be made, in order that they may bear most efficiently upon the problem.

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*Slightly abridged by Professor Campbell from his "Biennial Report to the President of the University of California," covering the period July 1, 1900, to July 1, 1902.

An institution whose efforts were confined strictly to securing observations would soon be making inferior observations. Progressive observers must be acquainted with the theories of their subjects, and must undertake occasional theoretical studies, as well as computations of considerable extent. The Director has constantly held in mind the necessity for increasing the efficiency of the Observatory wherever possible. The instruments have been kept in perfect repair, and efforts have been made to provide all desirable improvements. Lack of financial resources has necessarily limited the latter work to the most pressing cases.

The hydraulic engine for turning the dome of the great telescope had been working badly for several years, limiting to an appreciable extent the productiveness of the telescope itself. The expert machinist who had superintended the erection of the dome was employed in January, 1901, to examine its running mechanism, and to make the necessary improvements. It was found that the brass feed-cylinders of the engine were badly worn, permitting very considerable leakage, thereby in effect decreasing the hydraulic pressure on the pistons. The cylinders were drilled true, and new piston-heads were provided. It is gratifying to report that the dome and its entire mechanism now perform at least as satisfactorily as they did when new.

The original design of the great telescope did not provide for power to wind the driving-clock; it was wound by hand. A Pelton water-wheel was installed for this purpose in 1890, but it never had sufficient power to do the work without assistance from the observer. In the past year the water-power has been applied more directly to the wheel, and the crude device for communicating the power to the clock has been replaced by sprocket wheels and chain. The winding apparatus now acts immediately, without assistance from the observer.

Further to increase its efficiency, Mr. WRIGHT has designed, and the instrument-maker has constructed, a device for turning the water-power on and off automatically. This will be put in place in the near future; and it is hoped that the observer's duties in connection with the clock will be confined to starting it in the evening and stopping it in the morning.

The need of a wind-screen in the opening of the dome had been felt for many years. The violent vibration of the telescope when the opening was turned toward the wind made it impossible to secure accurate observations. A temporary screen was put in place in the fall of 1900, especially for use in the *Eros* campaign. This served its purpose so well that a permanent screen on analogous lines was designed in 1901 by our carpenter, and was manufactured and put in place by him.

It is necessary that frequent repairs be made to the great telescope. This is not at all surprising in view of the fact that this excellent instrument is used throughout every good night. A serious defect recently developed in the Right Ascension slow-motion and clamping trains. This gradually grew more troublesome, until in April, 1902, these trains suddenly refused to operate. Upon investigation it was found that the trouble existed at the junction of the polar and declination axes. Unfortunately, the construction was such that the critical point was not accessible. Repairs called either for the dismounting of the telescope-tube, the declination-axis, and many minor pieces, or for the cutting of a hole through the cast-iron sleeve of the declination-axis. The latter method seemed preferable. My plans for this purpose were submitted to the makers of the telescope, the WARNER & SWASEY COMPANY, and met with their approval. When the hole was cut, it was found that the important cast-iron bearing block, where the trains turn through a right angle, had broken. This block was replaced by a larger steel one, constructed in our shops. For the first time in its history, I believe, the telescope was disabled for observational work. This was for two days only, while the new block was making. The value of our instrument-making shop was well illustrated on this occasion. Had it been necessary to secure machinists and tools from a distance to cut the hole in the telescope, and to have the broken parts constructed elsewhere, a delay of several weeks must have ensued, and the expense would have been correspondingly great.

The efficiency of the 36-inch equatorial was enormously increased a few years ago by illuminating the setting-circles by means of electric lights operated from the eye-end, according to Messrs. CAMPBELL and WRIGHT's plans, thereby making it unnecessary for the observer to climb the high mounting, as he had theretofore done many times per night. Astronomer HUSSEY has recently equipped the twelve-inch equatorial (under his charge) in a similar manner, with good results.

Many minor improvements on the mounting of the Crossley reflector have contributed somewhat to its stability, but the necessity for providing this instrument with a new mounting has become more apparent with time to all who have used it. Director KEELER'S remarkable success was achieved at enormous expense of time and physical energy. On the average, it was necessary for him to make four or five exposures on an object before a suitable negative was secured; and in many cases he had to be satisfied with enlarged and elongated star images. His experiences have been those of Assistant Astronomer PERRINE, who is now in charge of the instrument. If the mirror were provided with a suitable mounting, observers possessing their great skill should have no difficulty in obtaining three successful negatives out of four attempts. The subject has been brought to the attention of the Lick Observatory Committee of the Regents, who have authorized the construction of a new mounting. Working drawings have been made by the firm of HARRON, RICKARD & McCONE in accordance with general designs supplied by Mr. PERRINE. Bids have been received from three responsible firms, and the contract is ready for letting. The smaller and more delicate parts of the mounting have been designed by Mr. PERRINE, and these will be constructed in our instrument-making shops. It is hoped that the change from old to new may be made before the end of the year.

The original driving-clock of the Crossley reflector was replaced several years ago by a vastly more powerful one, from designs by Mr. HUSSEY. With the installation of the new mounting, only the 36¼-inch mirror of the original telescope will remain in use.

A generation ago the astronomer ordered his telescope and expected it to meet all his requirements. This is no longer sufficient. The wonderful developments of our science call for special instruments to do special work, and the so-called universal instrument is out of date. This is especially true in investigations along astrophysical lines. The successful instrument must have maximum efficiency in the problem to be solved. Every observatory of our class requires an instrument-making shop near at hand. This requirement is especially pressing here, on account of our unusual isolation.

The shops at the Lick Observatory were entirely inadequate for their purpose. The equipment consisted of two small, antiquated foot-power lathes, an antiquated hand-drill, files, etc.; and the carpenter's hand tools. The quantity of construction possible by their means was small, many vital parts of the instruments could not be made at all, vexatious delays in construction elsewhere were frequent, and our plans were rapidly falling in arrears to such an extent that the efficiency of the Observatory suffered severely. I therefore decided to utilize any available budget funds for the improvement of the machine-shops.

The carpenter-shop, paint-shop, and forge occupied adjoining rooms in a small brick building near the great dome, constructed by the Lick Trust. The paint-shop was removed to an isolated building beyond the barn, both to diminish risks from fire and to increase the space in the carpenter-shop. The inside walls of the forge-room were likewise removed. The resulting shop is twenty feet by twenty-six feet. An addition to this shop was built by the Observatory workmen in 1891, inside dimensions twenty-five by thirty-three feet, from brick left in the original Lick Trust kilns. This room had been used for storage, for the metal-working shop, and for a steam boiler and engine employed in charging storage batteries and in cutting the Observatory wood. The engine and wood-saw were removed to a small brick building, outside dimensions eleven by fourteen feet, built in 1901 to the east of the barn; and storage space has been found elsewhere. The rearranged room admirably meets the requirements of a complete instrument-making shop, on the desired scale. A Foos four-horse-power gasoline-engine was installed in the shop in place of the steam-engine. It drives all the metal- and wood-working machines described below. It is always ready to start, without waiting for steam to rise; the expense of fuel is small; it does not need the attention of a fireman; and it does not heat the work-room unduly. A Brown & Sharpe No. 1 Universal milling machine, a Brown & Sharpe tool-grinding machine, a modern wood-turning lathe, a wood rip-saw and an emery grinder were purchased in 1901. The old foot-lathes were modified to adapt them to power. The necessary shafting, pulleys, belting, attachments and small tools were likewise provided. The gasoline-engine drives the dynamo also.

The thoughtful generosity of Mrs. HEARST has enabled me to arrange for the completion of the shops without the delay that I feared might occur, by purchasing a modern lathe of fourteen-inch swing and eight-foot bed, with all necessary attachments; a power drill; a power saw for cutting metal; a cross-cut saw for wood; a wood-shaper; a small tempering and reducing furnace; and minor tools.

The schoolhouse, though small, is very complete and comfortable. The school is attended by nine children of various members of the staff. The teacher is supplied by Santa Clara County.

A tract of forty acres of land adjoining the reservation on the east, formerly belonging to JACOB WANDELL, was purchased by the University in 1901. Its location made control by the Observatory extremely desirable.

The principal buildings have for many years been painted a dull red color. This color was not in keeping with the character of the institution, nor was the quality of the paint adapted to the requirements of our climate. The smaller buildings and the residences were painted in various colors, and the effect was not at all pleasing. It was decided to have the outsides of all the buildings on the mountain painted on a uniform system, the roof to be tile-red, and the walls to be light yellow sandstone color, all to match the colors of the old California Mission buildings. The change was made last year for many of the smaller buildings, and the main building is now undergoing transformation. The general effect promises to be all that could be desired.

With the advice and assistance of the President, to meet a pressing want, the Lick Observatory early in 1901 began to publish the results of its observations in the Lick Observatory Bulletin. The earlier papers by members of the staff had appeared in various astronomical journals. While this plan relieved the University of expense and considerable labor, yet the vexatious delays sometimes occurring in the issue of important papers, and the appearance of the papers in so many mediums, were serious objections. The new plan has worked well, and the Bulletins are in great demand. They have been supplied gratis to other observatories, to academies of sciences, and to the principal investigators. Twenty-seven numbers have been issued up to date, and the distribution list includes about 430 addresses. The funds available for last year did not permit the insertion of many illustrations. The increased appropriation for the year 1902 will provide for a greater number.

The Observatory library is growing rapidly, so far as growth by exchange of publications is concerned, but there have been almost no funds available for purchases. Early volumes of several scientific periodicals, early volumes of observatory reports now obtainable only from second-hand dealers, and many standard books, both old and recent, are greatly needed. It is planned to supply a few of the most pressing of these needs in the near future from the funds provided by Mrs. HEARST. The library contains about 5,000 volumes and 4,800 pamphlets. It has outgrown the capacity of the library-room. Suitable hardwood book-cases have been constructed in the main corridor for the overflow. In this way the space requirements will probably be met for many years. The library is in charge of Assistant Astronomer AITKEN.

Up to the beginning of the year 1901 it had been the practice of the directors of the Observatory to write all the letters personally. The correspondence has always been heavy, and the tax upon valuable time and physical strength for this purely mechanical labor has been very great. It seemed to me that modern methods should be adopted. The former Secretary's time had through experience become too valuable scientifically to justify his retention in that office. It was arranged that his services should be available entirely for investigational work, and a secretary who was also a stenographer was employed in his stead.

The arrangements inaugurated by Director KEELER regarding fellowships in the Lick Observatory have been very satisfactory. The immediate output of scientific results would be considerably greater if the funds, originally paid to an astronomer and now paid to the Fellows, could be used in the employment of regular assistants who would spend all their time on the mountain. But the training of the astronomers of the future is so manifestly one of the duties of the University that the arrangement should be continued.

The greater part of the time of the Fellows during their first two years of residence is devoted to assisting the astronomers in the more routine parts of their work; but with the acquirement of experience and skill, greater responsibilities are placed upon them, and the assignment of original investigations to them is planned in all cases.

It is a great pleasure to record the following generous gifts to the Lick Observatory:—

In December, 1900, D. O. MILLS, Esq., provided a fund of $24,000, plus ten per cent. for unexpected expenses, for a spectroscopic expedition to the southern hemisphere. This gift is noted more fully below.

WILLIAM H. CROCKER, Esq., provided a fund of $3,000 to defray the expenses of an expedition to Sumatra to observe the total solar eclipse of May 18, 1901. The work of the expedition is described in detail in other paragraphs.

A grant of $500 from the Draper Fund of the National Academy of Sciences was made in February, 1901, for the purpose of constructing a modern one-prism spectrograph. The designing of this instrument was delayed until the completion of the reflecting telescope for the southern hemisphere.

Mr. D. O. MILLS has presented the sum of $1,000 for the reconstruction of the original Mills spectrograph. It was built in the age of brass; the new instrument will be of steel in all its vital parts. It will also contain many important modifications resulting from our six years' experience with the original instrument. The reconstruction is now under way.

Mrs. PHŒBE A. HEARST has thoughtfully provided the sum of $2,500, available during the year 1902, to be expended for equipment purposes. As a result of her generous gift, several departments of the Observatory will be equipped for more efficient work.

The total value of these gifts in the past year and a half is $33,400.

The Wells, Fargo Express Company, on several occasions, granted half-rates on heavy and valuable shipments. In recognition of our time signals, the Southern Pacific Company has given reduced rates for passage and freight in connection with eclipse expeditions, shipment of heavy goods, etc. The Toyo Kisen Kaisha, the Occidental and Oriental Steamship Company, the Pacific Mail Steamship Company, and the Dutch East India steamship companies granted concessions to the Sumatra Eclipse observers. Prominent firms in San Francisco and in the East have in every case supplied tools for our instrument-shops at rates lower than commercial firms must pay. The total value of the concessions cited above approximates $1,800 for the past two years. The power of our resources to produce useful results was increased to that extent, and the thanks of the Observatory are due to the companies mentioned.

It was Director KEELER's purpose to secure with the Crossley Reflector satisfactory photographs of about one hundred of the principal nebulæ and star-clusters. The portions of his programme available for observation in our clear summer weather were practically complete at the time of his death, but those in position during the cloudy winter months were incomplete. We have made it a duty to carry on Director KEELER's work as rapidly as possible, but the necessity for securing observations of the planet *Eros* and of the eclipse in Sumatra has interfered to some extent. The amount of clear weather in the past winter and spring has likewise been very much less than the average, and gaps in this part of his programme still remain. As soon as satisfactory negatives of all the objects have been obtained, the results should be published in the best possible manner. The making of plates for reproducing the photographs will be a very painstaking and expensive process, but it is hoped that funds may be obtained from private sources to an amount sufficient to do justice to Dr. KEELER's work and memory.

Through the continued generosity of Mr. WILLIAM H. CROCKER, a well-equipped expedition, in charge of Acting Astronomer PERRINE, accompanied by Assistant RALPH H. CURTISS, sailed from San Francisco in February, 1901, to observe the total solar eclipse of May 18th, on the west coast of Sumatra. The affairs of the expedition, personal, financial, and scientific, were admirably managed by Mr. PERRINE. The ten instruments were duly mounted and placed in perfect adjustment. Fifteen volunteer assistants, Dutch residents in Sumatra, were trained to their duties, and the entire programme of photographic exposures outlined for the expedition went through without a hitch. All went well, save that the eclipsed Sun was obscured at the beginning of totality by thin clouds, which gradually thickened during the 6½ minutes of the eclipse.

To the surprise of the observers, when the negatives were developed it was found that the observations were extremely satisfactory, valuable results having been secured with all of the ten instruments. The instruments and photographs were delayed in transit homeward, and did not reach Mt. Hamilton until October. Examination of the plates more than confirmed Mr. PERRINE's report. A study of the photographs has shown that, in spite of the thin clouds, the expedition was at least as successful as any eclipse expedition ever sent out by any institution.

The general results have been published in a preliminary manner in Lick Observatory Bulletin No. 9, but attention should be called to a few of the more important ones:—

The photographs obtained with the forty-foot camera are admirable, the general features of the inner and middle corona being shown as well as if there had been no clouds. A most interesting and unique coronal disturbance was recorded in position-angle 60°. A comparison of the solar photographs with those made on the days preceding and following the date of the eclipse by English observers in India led to the very important conclusion that the coronal disturbance was situated immediately above the prominent and only sun-spot group visible on those days.

The spectrographic and polarographic results were completely successful, perhaps more so than would have resulted from an unobscured eclipse. They established that the spectrum of the outer corona is identical with that of ordinary sunlight, and therefore that the light of the outer corona is not inherent, but is reflected light originating in the main body of the Sun; that the spectrum of the inner corona is continuous, and therefore is not reflected sunlight, but is inherent; that the outer corona shows the strong polarization effects that would be expected to result from its character as reflected light; and that the inner corona gives only slight evidence of polarization, as would be expected from light largely of an inherent character.

Mr. PERRINE has carefully examined the plates secured with four cameras for the purpose of detecting any possible intra-Mercurial planets. The instruments gave splendid definition, and in the unobscured areas surrounding the Sun stars down to the ninth magnitude were recorded. The search was highly satisfactory for more than two thirds of the area under examination, but the clouds prevented complete success in the remaining one third. No unexpected objects were detected. While the discovery of unknown objects as a result of this search would have been more interesting, yet negative and positive results would possess equal value scientifically.

The expedition received very extensive help from the Dutch Government in Sumatra, from the lines of steamers patronized, and from individuals at all transfer points.

Mr. CROCKER'S services to eclipse astronomy have been highly appreciated by astronomers and other men of science throughout the world.

The discovery of the minor planet *Eros* in 1898, and the recognition of the unusual opportunities offered by it for an improvement in our knowledge of the distance of the Sun, led to the organization of a coöperative scheme on the part of forty or fifty leading observatories, to secure the necessary observations in the fall of 1900. The Lick Observatory entered energetically upon the programme outlined. Astronomer TUCKER secured more than two thousand meridian-circle observations of the 678 reference stars, required as a basis for the entire problem. The microscopes were read by Dr. R. T. CRAWFORD for about 1,600 of the observations, and he rendered some assistance in the computations, but Mr. TUCKER was unassisted in the bulk of the reductions. The results were published in Bulletins Nos. 1 and 2, in February and May, 1901, respectively. The prompt completion and publication of this extensive piece of work, long in advance of the appearance of results from the other observatories, called forth many expressions of surprise and admiration for the energy and skill of the astronomer in charge.

Careful micrometer measures of the position of *Eros* were obtained by Astronomer HUSSEY and Assistant Astronomer

AITKEN, with the thirty-six-inch equatorial. The former made 832 measures in Right Ascension, and 896 in Declination; the latter 1,650 in Right Ascension and 729 in Declination. Photographic observations were secured in great numbers with the Crossley reflector by Assistant Astronomer PERRINE, assisted by Fellow H. K. PALMER. They include 344 plates on sixty-three nights for accurate meridian places of the planet; 511 plates on thirty-seven nights for a parallax; 110 charting and connecting plates; total, 965 plates, of which 854 contain short exposures for measurement, carrying over four thousand images of the asteroid. The micrometer results, and a list of the photographic plates, are published in Bulletin No. 13. The measurement and reduction of these plates will be an enormous task. Fortunately, Professor REES, Director of Columbia College Observatory, has agreed to undertake that work. His efficient bureau of measurement and reduction, in immediate charge of Professor JACOBY, has already measured and reduced a number of the plates.

Perhaps the most interesting astronomical events of recent years relate to the new star in *Perseus,* discovered in Edinburgh on February 22, 1901. The Lick Observatory, in common with all similar institutions, made immediate plans to bring every available resource to bear upon the study of this star. Its position was measured by Mr. TUCKER with the meridian-circle, and by Mr. AITKEN with the thirty-six-inch equatorial on several occasions in the spring and summer of 1901. It is clear from their observations, amply confirmed by those made elsewhere, that the new star is at least as far away as the faint stars surrounding it, and that its motion with reference to the surrounding stars is so slight as to elude detection for the present. Our two spectroscopes suitable for the study of the new star were sent to Sumatra with the Eclipse Expedition only two or three days before the announcement of the discovery reached us. Fortunately, the Observatory possessed a good collection of lenses and prisms; and from these, spectroscopes were mounted very promptly in our instrument-making shops, so that practically no time was lost on that account. The spectroscopic observations by Messrs. CAMPBELL and WRIGHT, assisted by Dr. REESE, were extremely fruitful in results. They have been published in Bulletin No. 8.

Spectrum photographs were secured by Fellow Joel Stebbins with the Crossley reflector, which led to the discovery of two new bright lines in the ultra-violet portion of the spectrum. The brightness of the star was observed on all possible occasions, during its period of rapid fluctuation, by Messrs. Aitken and Stebbins. It was the brightest star in the northern sky on February 24th; it has now declined to the ninth magnitude, having been in the mean time converted into a nebula.

A photograph by Wolf, of Heidelberg, on August 23, 1901, had led to the discovery of masses of nebulosity in the vicinity of the new star. A photograph by Ritchey, of the Yerkes Observatory, on September 20th, confirmed and extended the discovery, showing that the new star was apparently situated in a nebulous mass nearly circular in form, and of great extent. The photograph of this region made by Mr. Perrine with the Crossley reflector, on November 7th and 8th, led to the extraordinary discovery that the well-defined nuclei in the nebula were apparently in rapid motion; the magnitude of the apparent motion being at least seventy-five times as great as any sidereal motion previously known. Telegraphic announcement of this discovery was made at once, and intense interest was taken in the subject. A photograph made by Ritchey at the Yerkes Observatory, on November 9th, afforded full and independent confirmation of Mr. Perrine's remarkable discovery. Photographs made at intervals throughout the winter have enabled us to follow the motions of the brighter masses.

Following this discovery, there were frequent expressions of regret that no record of the nebulosity had been obtained between the discovery of the star in February and the epoch of Wolf's photograph. Numerous short-exposure plates of the new star had been obtained by Messrs. Palmer and Dall with the Crossley reflector early in the year. Examination of these by Mr. Perrine in January, 1902, led to the happy discovery that two rings of nebulosity surrounding the new star were beautifully recorded on Mr. Palmer's plate of March 29th. We were thus able to extend the history of the phenomenon backward five months.

The nature of the phenomenon is a mooted question. The favorite theory is that invisible masses of nebulosity existed in this region previous to the formation of the new star; and that the great wave of light, sent out when the brightness of the star was at a maximum, was sufficient to illuminate the dark masses and make them visible to us by reflected light. Bearing upon this question, Mr. PERRINE secured valuable polariscopic evidence. A photograph of the nebula was obtained after passing the light through a double-image prism, placed at a short distance in front of the plate-holder in the Crossley reflector. Two images of each of the principal nuclei were recorded in such a way as to make it certain that the polarization effects to be expected from reflected light are entirely absent. It is hoped that a complete series of observations of this interesting object may be obtained during the coming autumn, and that the principal masses will be bright enough to permit a study of their spectra by means of a small spectrograph that Mr. PERRINE has planned.

The consensus of opinion is that the new star is the result of a violent collision between two dark stars, or between a dark star and a nebula. It can easily be shown that the kinetic energy of two such bodies, approaching and colliding with enormous relative speed, would be converted into heat in sufficient quantities to transform the dark bodies into incandescent gases. The history of previous new stars had led us to expect that the spectrum would gradually change into that of a nebula, and in this we were not disappointed. For a suitable study of the present nebular spectrum of the new star it was necessary that further and more accurate investigations be made upon the spectra of the well-known nebulæ. These investigations were undertaken with great success by Assistant Astronomer WRIGHT. His results have been published in Bulletin No. 19. Not only did he determine the positions of many well-known nebular lines more accurately than had previously been done, but a number of very interesting new lines were detected.

Very little attention has been given to the subject of comet-seeking, on account of pressure of work in other lines, although search has been made by Mr. PERRINE for a few periodic comets whose returns were expected. These include the Di Vico-Swift comet, BARNARD'S comet of 1884, and SWIFT'S comet of 1895. No trace of these was discovered, no doubt on account of their faintness, or of their defective orbits.

Micrometer observations of comets in the past two years have been secured, as follows:—

Comet *a* 1900,	AITKEN, 3 nights,	PERRINE, 4 nights.
" *b* 1900,	" 10 "	" 3 "
" *c* 1900,	" 6 "	
" *a* 1901,	" 2 "	
" *a* 1902,	" 2 "	

The measures of Comet *a* 1901 and of Comet *a* 1902 were the only ones made in the United States. Valuable photographs of Comet *a* 1901 were secured by Mr. PERRINE at the Eclipse Station in Sumatra. An orbit of Comet *b* 1900 was computed by Mr. PERRINE, and of Comet *c* 1900 by Mr. AITKEN. Some very interesting photographs of Comet *b* 1900 were secured by Mr. PALMER.

Extensive series of measures of satellites of planets were obtained by various members of the staff, observations being limited in all cases to those most desired by investigators of their orbits.

Two hundred and fifteen observations of the relative positions of the satellites of *Saturn* were made by Mr. HUSSEY with the thirty-six-inch equatorial.

Mr. AITKEN made the following observations with the thirty-six-inch equatorial:—

Satellites of *Uranus*,	2, nights.
" " *Neptune*,	13 "
" " *Mars*,	7 "
Fifth satellite of *Jupiter*,	2 "

At the request of Professor NEWCOMB, Mr. PERRINE photographed the planet *Neptune* and its satellite on thirty plates, in January, 1902, with the Crossley reflector. The measurements of these plates furnish fifty-one determinations of the position of the satellite, with reference to its primary. Photographic methods have been but little used in this line of work, and it is interesting to note that the smallness of the errors of observation justifies the application of the method in all possible cases.

The work with the meridian-circle has been most efficiently prosecuted. Since July 1, 1900, Mr. TUCKER has obtained 6,500 complete observations. These include observations of *Eros* comparison-stars; of *Eros* itself; of *Nova Persei*; and of zodiacal stars, greatly needed at the present time, to be used as a basis for improving the orbits of the major planets.

The manuscript for *Lick Observatory Publications*, Volume VI, is entirely ready for the printer. The volume will contain results of meridian-circle work from July, 1896, to March, 1901, and will include about 14,000 complete observations of 4,500 stars. The labor entailed in securing, reducing, and preparing these observations for publication has been very great. Mr. TUCKER has had assistance from Messrs. CRAWFORD, DALL, CURTISS, and PALMER, amounting to about six months full time of one computer during the past two years. The remainder of the work has been carried on without assistance.

Fellow R. T. CRAWFORD assisted in meridian-circle work during the years 1898-1901. At the end of his service he received the degree of Doctor of Philosophy, having taken for his thesis the subject of "The Refraction-Constant at Mt. Hamilton."

The department of astronomy known as Double Stars has been most ably advanced by Messrs. HUSSEY and AITKEN. The former has devoted perhaps three fourths of his time and the latter one half his time to this line of investigation. Their programmes have been admirably developed and systematized, and results of prime importance have been surprisingly numerous. It is not too much to say that their discoveries and observations of new double stars, and their measures of known double stars, outnumber several-fold the corresponding output of all other observatories in the past two years. An equally satisfactory statement can be ventured as to the accuracy attained. Both observers have devoted a portion of their time to the discovery of new pairs. Mr. HUSSEY has found 312 systems in the past two years, and 564 since 1898. They may be classified as follows:—

Distances between	0".00	and	0".25,	41 pairs.
	0 .26	"	0 .50,	103 "
	0 .51	"	1 .00,	123 "
	1 .01	"	2 .00,	128 "
	2 .01	"	5 .00,	168 "
		Over	5 .00,	1 "
			Total	564 pairs.

It will be seen that 47 per cent of his discoveries have distances less than 1″, and 70 per cent less than 2″.

The corresponding discoveries by Mr. AITKEN have been 249 since July, 1900, and 345 since 1898, as follows:—

Distances between	0″.00	and	0″.25,	20 pairs.
	0 .26	"	0 .50	55 "
	0 .51	"	1 .00,	78 "
	1 .01	"	2 .00,	91 "
	2 .01	"	5 .25,	101 "
			Total	345 pairs.

Forty-five per cent of these are under 1″, and 71 per cent under 2″.

By way of explanation, it should be said that in general the closer the components of a pair the more interesting and important it is. The majority of stars in which orbital motions have been detected are closer than 1″. Up to the present time about 1,500 double stars with distances under 1″ have been discovered at all the observatories. More than one third of these have been found at the Lick Observatory, and more than one fourth of the whole number have been discovered here within the last three years.

Many interesting results have come from the systematic observation of the well-known interesting pairs. Of these, the most striking case is δ *Equulei*. It was supposed that its period of revolution was 11.4 years,—surpassed in rapidity of motion only by κ *Pegasi*, period 11⅓ years. In the fall of 1900 it was noticed by Mr. AITKEN that the components of δ *Equulei* were not following the paths marked out for them by the orbit hitherto accepted as substantially final. Mr. HUSSEY investigated the question of their orbit, making use of all the known observations. He came to the conclusion that the chances were greatly in favor of a period only one-half the length of that previously assumed, namely, 5.7 years. Systematic observations by Messrs. HUSSEY and AITKEN during the past year have established the correctness of this view. The period of this interesting binary is fifty per cent shorter than that of any other known double star. Observations of this system obtained with the Mills spectrograph are in harmony with Mr. HUSSEY's theory.

Mr. Hussey has also in the past two years secured

881 micrometrical observations of newly discovered pairs.
801 " " " W. Struve pairs.
54 " " " Otto Struve pairs.
63 " " " miscellaneous pairs.
Total, 1,899

Mr. Aitken has obtained 1,431 observations, his observing-list being mainly composed of known rapid binaries, and other close and difficult pairs. He has likewise computed orbits for 99 *Herculis*, *ζ Sagittarii*, and *β Delphini*.

Mr. Hussey completed his observations and discussions of the Otto Struve double stars, and his work was issued in the summer of 1901 as Volume V, *Publications of the Lick Observatory*. This volume is of great utility to double-star observers. It met with an excellent reception from his fellow-workers.

In the year 1900, the Lick Observatory agreed to coöperate with the Harvard College, Yerkes, and University of Virginia observatories, in observing photometrically ten stars in the immediate vicinity of each of thirty-six well-known variable stars, under the auspices of the Rumford Committee of the American Academy of Arts and Sciences. The photometer was designed and supplied by Professor Pickering, Chairman of the Committee; but, on account of the greater brightness of the images formed by the thirty-six-inch telescope, it was necessary to change its form before beginning observations. The work on *Eros*, the solar eclipse, and the new star, combined with the smallness of our staff, delayed work on the programme until June of this year. Results are now rapidly being obtained by Mr. Aitken and Dr. S. D. Townley, of the Berkeley Astronomical Department, who spent his summer vacation here in several phases of photometric work.

The Crossley reflector has been busy on practically every good night. In addition to the observations already referred to, Messrs. Palmer and Dall made thirty-three exposures on the nebulæ contained in Professor Keeler's programme, in the first half of 1901. Mr. Perrine has since secured twenty-three exposures on these nebulæ, twenty-eight exposures on the Rumford variable star regions referred to above, and twenty-five exposures for miscellaneous purposes. Fellows

PALMER, STEBBINS, and CURTISS have ably assisted in the observations with the Crossley reflector.

A small slitless spectrograph was designed by Professor KEELER for use on faint objects with the Crossley reflector. It was completed on the day of his departure from the mountain. It was tested promptly by Messrs. CAMPBELL and PALMER, who found it necessary to use convex and concave quartz lenses in connection with the quartz prism, in order that the rays should be parallel when passing through the quartz prism. These changes were designed by Mr. PALMER, and the instrument was used extensively by him. He secured seventy spectrograms of the smaller planetary nebulæ and of other small objects. Many interesting facts resulted from these observations. I shall refer only to his success in photographing extremely faint spectra. A strong image of the spectrum of *Nova Cygni,* visual magnitude about 15.5, was obtained with ease. Successful exposures could probably be made on stars at least a magnitude fainter. His photograph of *Nova Cygni* demonstrates that the spectrum, which was nebular in 1877, has now become continuous, like that of the ordinary stars.

In addition to the observations of *Eros,* positions of asteroids *1900 GA, Ohio,* and *Palatia,* were determined by Mr. PALMER, from photographs taken with the Crossley reflector. Mr. HUSSEY secured eight observations of the asteroids *Minerva, Edna,* (440), and *Chicago.* Messrs. PALMER and CURTISS have recently secured photographs of several asteroids whose positions were requested, and the plates are being measured by Mr. CURTISS.

Mr. PERRINE has made 200 copies on glass of the eclipse photographs secured in India in 1898, in Georgia in 1900, and in Sumatra in 1901, for distribution to institutions, to societies, and to individual investigators taking special interest in this subject.

Three nights per week with the 36-inch equatorial have been devoted to the determination of the motions of the brighter stars in the line of sight, with the Mills spectrograph, during the past six years. The importance of line-of-sight investigations is attested by the fact that nearly all the powerful telescopes in the world are devoted at present largely to this purpose, though with varying degrees of success. The accuracy of the Lick Observatory determinations has steadily progressed until, for the stars containing fine lines, the probable error of a single determination of velocity is only about 0.25 kilometer.

To the list of fifteen spectroscopic binaries discovered prior to Director KEELER's report of July 1, 1900, I desire to make twenty-three additions, as follows:—

β *Herculis,*
ξ *Ursæ Majoris,*
δ *Bootis,*
113 *Herculis,*
η *Andromedæ,*
π *Cephei,*
ξ *Piscium,*
ξ′ *Ceti,*
δ *Equulei,*
ζ *Herculis,*
o *Andromedæ,*
γ *Canis Minoris,*
12 *Persei,*
93 *Leonis,*
β *Scuti,*
2 *Scuti,*
κ *Pegasi,*
31 *Cygni,*
τ *Persei,*
ε *Hydræ,*
α *Equulei,*
φ *Persei,*
η *Geminorum.*

These thirty-eight systems have been discovered since 1898. The satisfactory character of the results obtained with the Mills spectrograph, both in quantity and in quality, may be inferred from the fact that during the time these thirty-eight spectrographic binary systems were coming to light as a result of our work, only eight similar systems were announced by other observatories, and three of the eight were erroneous.

There is room for reference to only two of the stars on the above list: ζ *Herculis* is a short-period visual binary star, completing a revolution in about thirty-three years. The velocity of the principal star in the line of sight is slowly varying. κ *Pegasi* is one of the most interesting visual binaries known, period 11⅓ years. Until the discovery of the true period of δ *Equulei,* this was supposed to be the shortest period known. One of the components of κ *Pegasi* is a spectroscopic binary, having a period of only six days.

These binary systems have been discovered in the process of determining the velocities of about 350 stars; in this list of 350, previous observers had discovered three binaries. Without taking into account a list of several suspected binaries, it is apparent that of the brighter stars at least one in every seven or eight is attended by an invisible companion. When we consider that spectroscopic methods are at present capable of discovering only the larger variations, that very few stars of long periods have probably been advantageously observed as yet, and that the velocity of our Sun, due to the orbital motions of the planets attending it, has a double amplitude of only two or three hundredths of a mile per second, there can be no doubt that the number of spectroscopic binaries must be very great. It is probable that the star unattended by dark companions will be found to be the exception rather than the rule.

Mr. WRIGHT has computed the orbit of the spectroscopic binary χ *Draconis.* Dr. REESE has computed the orbit of the spectroscopic binary *Capella.* Director CAMPBELL has computed the orbit of the variable star and spectroscopic binary ζ *Geminorum.* Dr. CRAWFORD has computed the orbit of the spectroscopic binary η *Pegasi.*

Dr. REESE, at my request, investigated the question of the diffraction of light of variable intensity, with special reference to the Mills spectrograph, as a guide in designing a, more powerful instrument. He has likewise investigated the cause of the discrepancies between measures of spectrograms made with the violet end to the left, and with the violet end to the right, as a result of which he established the purely physiological cause of the discrepancy.

Dr. REESE has also designed the new mounting for the Mills spectrograph, referred to in a previous paragraph.

Photographs and preliminary measures of several hundred spectra have been made by Messrs. CAMPBELL, WRIGHT, and REESE; and a considerable number of definitive measures have been made.

In December, 1900, the Director utilized the results obtained for the velocities of 280 stars situated north of —20° Declination in determining the speed and direction of the motion of the solar system through space. The result for the speed of the solar system comes out 19.9 kilometers, or 12.4 miles per second. The apex of the motion is in R.A. 277° 30′, Declination +20°. The result for speed is very satisfactory. On account of the absence of material from the southern hemisphere, and the consequent irregular distribution of the observed stars over the sky, the direction assigned must be regarded as a rough approximation.

The average velocity in space of the 280 stars is 34.1 kilometers per second. The velocity of the solar system is therefore much less than the average for the other stars.

Another result of great interest is to the effect that the fainter stars are moving much more rapidly than the brighter ones.

The velocities of the stars have been observed to bear all values between sixty miles approach and sixty miles recession per second.

Investigations in this line have been shown to be practically endless, by our measurements of the velocity of the star *Groombridge 1830*. A special effort was made to measure its velocity, as this is the star which up to three years ago had the largest known proper motion. Its photographic magnitude is in the neighborhood of 7.5. The results obtained have shown that the observations may be extended by present methods to stars perhaps a magnitude fainter. Stars available for measurement are therefore numbered by thousands. As soon as half a dozen of the eight or ten great telescopes now engaged in this work have been made to produce accurate results, it will be highly desirable that the interested observatories arrange and carry out a scheme of coöperation on a large scale.

From Mt. Hamilton it is possible to secure the speeds of the stars between the North Pole and 30° South Declination. The stars in the quarter of the sky from 30° South to the South Pole remain unobserved. For many years it has been my desire to organize an expedition to the southern hemisphere for the purpose of measuring the velocity of these stars. The time for organizing this expedition seemed to have come in the winter of 1900. With the approval and indorsement of the President, the subject was brought to the attention of Mr. D. O. MILLS, who most generously offered to provide funds for constructing the instruments, for defraying traveling expenses, and for paying the salaries of the astronomers engaging in the work. It was decided to construct a reflecting telescope mounting to carry the extra 36¼-inch mirror that was in our possession, first cutting a hole through the center of the mirror in order that the Cassegrain form of mounting could be utilized. It was known that the mirror was of imperfect figure, and it was planned to have the JOHN A. BRASHEAR COMPANY refigure it after the hole had been cut. Unfortunately, in the process of cutting, the mirror broke in pieces on account of its enormous internal strains. This was not a misfortune, as Dr.

BRASHEAR reported that, on account of its very imperfect annealing, this piece of glass could never have been made to work well. A new mirror was ordered at once.

The telescope mounting, designed in general features by the Director, was brought to the mountain in December, 1901.

A powerful three-prism spectrograph, designed by the Director for use with the reflecting telescope, is completed. The delicate parts of the mounting were constructed by our instrument-maker, and the optical parts by the JOHN A. BRASHEAR COMPANY. Mr. WRIGHT has submitted the whole spectrograph to severe tests. Its performance appears to be superior even to that of the original Mills spectrograph. A modern steel dome was built for the expedition by the WARNER & SWASEY COMPANY, and was shipped to San Francisco on June 21st. The minor pieces of apparatus required have all been provided. It is planned to select a suitable observing-station in the vicinity of Santiago, Chile. It is confidently hoped that this work will be at least as fruitful as that carried on with the Mills spectrograph attached to the thirty-six-inch equatorial.

The Director wishes to make full acknowledgment of the enthusiastic support afforded him by the members of the Observatory staff. Every man has been ready to make the most of the opportunities supplied by the splendid instruments, by the unexcelled climatic conditions, and by the excellent policy inaugurated for the Observatory by the officers of the University of California.

W. W. CAMPBELL, *Director*.

GENERAL NOTES.

Astronomy in the Carnegie Institution.—In *Science* for January 30th, President DANIEL C. GILMAN, of the Carnegie Institution, publishes a detailed account of the proceedings of the Institution during the first year of its existence. From this account we extract such information as is of especial interest to astronomers.

In order to determine what work should be entered upon by the Institution, an advisory committee was appointed in each of eighteen sciences; that for astronomy is made up of E. C. PICKERING (Harvard), LEWIS BOSS (Albany), GEORGE E. HALE (Yerkes Observatory), S. P. LANGLEY (Smithsonian Institution), and SIMON NEWCOMB. Some other names well known in astronomy are to be found among the other committees: ORMOND STONE *(Mathematics)*, R. S. WOODWARD, and A. A. MICHELSON *(Physics)*, T. C. CHAMBERLIN *(Geology)* and CLEVELAND ABBE *(Meteorology)*.

At its meeting in November, 1902, the Board of Trustees made the following appropriations for research, aggregating $185,200:—

Astronomy	$21,000
Bibliography	15,000
Botany	11,700
Chemistry	3,000
Economics	15,000
Engineering	4,500
Exploration	5,000
Geology	12,000
Geophysics	8,500
History	5,000
Investigation of project for southern and solar observatory	5,000
Investigation of project for physical and geophysical laboratories	5,000
Investigation of natural history projects	5,000
Marine biological research	12,500
Paleontology	1,900
Physics	4,000
Physiology	5,000
Psychology	1,600
Publications	5,500
Research assistants	25,000
Student research work in Washington	10,000
Zoölogy	4,000

It will be seen that the appropriation for astronomy is considerably in excess of that for any other science, even without the $5,000 allotted to an investigation of the project for a southern observatory. The reason for this will be found in the avowed objects of the Institution, to favor those projects which seem to require immediate assistance, and to avoid coming into competition with other agencies for the promotion of research.

Some of the grants in astronomy are as follows: $2,500 to Harvard Observatory, to assist in a more thorough study of the astronomical photographs that are being made at Cambridge and at Arequipa; $4,000 to the Yerkes Observatory, for an investigation of stellar parallaxes by means of photography, investigations in stellar photometry, a study of several hundred photographs of the Sun taken at Kenwood Observatory in the years 1891 to 1896, and for certain other investigations in solar and stellar spectroscopy; $4,000 to the Lick Observatory, to be expended in the employment of assistants and computers; $1,000 to Vassar College Observatory, to make measurements and reductions of photographs of stars in the region of the north pole of the heavens. We regret that we cannot give a complete list of the separate grants in astronomy. The secretary of the Institution informs us that the trustees have decided to leave the announcement of grants to such of the grantees who may desire to make them.

Recent Meetings of Astronomical Societies.—This country now has two societies of professional astronomers: the Astronomical and Astrophysical Society of America, and Section A (*Mathematics* and *Astronomy*) of the American Association for the Advancement of Science. These societies are in no sense rivals, especially since the affiliation of the former with the American Association. The two now hold meetings at the same time in the same city, and the privileges of the meetings of each are extended to the members of the other. The meetings for this year were held at Washington during "convocation week," beginning Monday, December 29, 1902.

The Astronomical and Astrophysical Society elected the following set of officers for 1903:—

President—Simon Newcomb.

First Vice-President—George E. Hale.

Second Vice-President—W. W. Campbell.

Treasurer—C. L. DOOLITTLE.

Councilors—ORMOND STONE, W. S. EICHELBERGER.

Secretary—GEORGE C. COMSTOCK.

Besides Professor NEWCOMB's address on "The Universe as an Organism," the following papers were read:—

H. JACOBY: Photographic Measures made with the *réseau* and without.

GEORGE E. HALE, FERDINAND ELLERMAN, and J. A. PARKHURST: The Spectra of Stars of SECCHI's Fourth Type.

W. J. HUMPHREYS: Certain Matters Connected with Spectroscopic Methods.

E. B. FROST and W. S. ADAMS: (1) Radial Velocities of Twenty Stars having Spectra of the *Orion* Type. (2) New Spectroscopic Binaries. (3) The Wave-lengths of Rydberg's First Line of Hydrogen (λ 4686) and Others.

W. S. ADAMS: The Orbit of the Spectroscopic Binary η *Orionis.*

E. O. LOVETT: (1) Periodic Solutions of the Problem of Four Bodies. (2) On the Integrals of the Problem of n Bodies.

G. C. COMSTOCK: The Masses in 85 *Pegasi.*

F. W. VERY: Form and Structure of the Galaxy.

S. A. MITCHELL: Neon, Krypton, and Zenon in the Chromosphere.

G. C. COMSTOCK: Proper Motions of Faint Stars.

SARAH F. WHITING: Astronomical Laboratory Work.

F. W. VERY: Cause of the Nebulosity Around *Nova Persei.*

G. W. HOUGH: The Mounting of Fixed Meridian Instruments.

J. A. PARKHURST: Faint Variable Stars.

S. C. CHANDLER: The Value of the Aberration Constant.

C. L. DOOLITTLE: Constant of Aberration from Observations in 1901-1902.

E. F. NICHOLS and G. T. HULL: The Pressure of Light.

E. E. BARNARD: (1) Triangulation of Stars in Four Globular Clusters. (2) Observations of Variable Stars in Globular Clusters.

A. O. LEUSCHNER: (1) Short Method of Determining Orbits. (2) A Method of Computing Orbits in Rectangular Coördinates. (3) The Solution of the Orbit Irrespective of Parallax and Aberration. (4) The Orbit of Comet 1902 a.

G. H. PETERS: The Photoheliograph of the Naval Observatory.

SIMON NEWCOMB: Statement of the Progress made by the Watson Trustees in Computing Tables of the Watson Asteroids.

A. S. FLINT: Meridian Observations for Stellar Parallax.

L. A. BAUER: Magnetic Results during the Eruption in Martinique.

S. D. TOWNLEY: The Light of the Stars.

Abstracts of most of these papers may be found in *Science* for February 27, 1903; and President NEWCOMB'S address is printed in full in *Science* for January 23, 1903.

Section A of the American Association elected OTTO H. TITTMANN as Vice-President for the next meeting and L. G. WELD as Secretary. An address "On the Physical Constitution of the Planet *Jupiter*" was delivered by Professor G. W. HOUGH, and is printed in *Science* for January 16, 1903; in the same place may be found abstracts of the papers read before the meetings, the titles of which follow:—

O. H. TITTMANN: Deflections of the Vertical in Porto Rico.

L. G. WELD: SAINT LOUP'S Linkage.

S. P. LANGLEY: A Device to Prevent Personal Equation.

S. P. LANGLEY: The Solar Constant and Related Problems.

S. P. LANGLEY: Good Seeing.

PAUL CARUS: The Foundations of Mathematics.

F. H. BIGELOW: Structure in the Mass of the Sun.

P. LOWELL: Spectroscopic Proof of the Rotations of *Jupiter*, *Saturn*, and *Venus*.

G. B. HALSTED: The Teaching of Geometry.

E. O. LOVETT: Special Periodic Solutions of the Problem of *n* Bodies.

E. O. LOVETT: The Problems of Three or More Bodies with Prescribed Orbits.

ASAPH HALL: Secular Perturbations of the Planets.

G. B. HALSTED: The BOLYAI Centenary.

C. J. LING: Approach of Comet *b* 1902 to *Mercury*.

G. A. HILL: An Untried Method of Determining the Constant of Refraction.

J. T. QUINN: Development of Conic Sections by Kinematic Methods.

G. C. COMSTOCK: Time Determinations at Washburn Observatory.

C. S. HOWE: Determination of Time by Reversing on Each Star.

JAMES S. MILLER: Geometrical Analysis.

C. J. KEYSER: BOLZANO'S Contributions to Assemblage Theory.

C. W. FREDERICK: The Constants of the Equatorial.

LUIGI D' AURIA: A Relation between the Mean Speed of Stellar Motion and the Velocity of Wave Propagation in a Universal Gaseous Medium.

E. L. LARKIN: Condition of Seeing, etc., at Lowe Observatory.

The following grants have been made by the Rumford Committee of the American Academy of Arts and Sciences: To Dr. R. S. MINOR, $250 for a research on the dispersion and absorption of ultra-violet radiations; to Dr. S. D. TOWNLEY, of Ukiah, Cal., $100 for a stellar photometer; to Professor E. B. FROST, of the Yerkes Observatory, $200 for a special lens to be used in connection with the Bruce spectrograph in the study of velocities in the line of sight; to Professors E. F. NICHOLS and G. F. HULL, of Dartmouth College, $250 for a research on the relative motion of earth and ether; to Professor GEORGE E. HALE, of the Yerkes Observatory, $300 for a Rowland grating to be used in studying the spectra of the brightest stars.

During the illness of Professor JOHN K. REES, who has taken a leave of absence until next fall, Professor HAROLD JACOBY is in charge of the Astronomical department at Columbia University. Dr. CHARLES L. POOR, formerly associate professor of astronomy at the Johns Hopkins University, has been appointed lecturer in astronomy at Columbia University. Dr. SIDNEY D. TOWNLEY, of the University of California, has been appointed observer at the International Latitude Station at Ukiah. Doctor TOWNLEY will take charge of the station on May 1st; from February 1st until this later date the time will be spent in alternate observing by Doctor Townley and the present observer for the purpose of determining whether a change of observers will have any apparent effect upon the latitude. The vacancy caused by Doctor Townley's resignation from the Berkeley Astronomical Department of the University of California has been filled by the appointment of Doctor Russell Tracy Crawford, examiner to the U. S. Civil Service Commission.

Doctor Charles Dufour, professor of astronomy at Lausanne, Switzerland, is dead. On January 16th, died Professor E. A. Fuertes, Director of the A. C. Barnes Astronomical Observatory at Cornell University. Professor Fuertes was born in Porto Rico in 1838; he was much more prominent in engineering than in astronomy. Professor William Harkness, late Director of the Nautical Almanac, and one of the most prominent of American astronomers, died on February 28th; we hope to give later a sketch of his career.

For the following accounts of Sir G. G. Stokes and of James Glaisher, who died recently in England, we are indebted to Mr. Andrew Greig, of Dundee, Scotland:—

"Sir George Gabriel Stokes, of Cambridge, England, died 1st February, 1903. It was in 1841 that he took his degree as Senior Wrangler. In 1849 he was elected to fill the chair of Lucasian Professor of Mathematics at Cambridge—once occupied by Newton; and three years after became a Fellow of the Royal Society, and from 1885 to 1890 he acted as President of that distinguished body. No occupant of Newton's office so closely resembled the great master. In the quality and direction of their studies, in the perfection of their analysis, and in the devout reverence for the cause of causes in Nature, they were men of the same order. Stokes's favorite study was the science of light. It was said of him that 'if you give Stokes three-quarters of an hour of sunlight, there is no experiment in optics that he cannot perform for you.' He received two medals from the Royal Society; held honorary degrees of several universities; and was President of the British Association in 1869.

"Sir Gabriel Stokes was one of the foremost mathematicians of his time. Among scientific men of his generation he stood very high. Lord KELVIN once called him 'the teacher and guide of his contemporaries,' and the esteem in which he was held in the world of learning was abundantly illustrated on the occasion of his jubilee as Lucasian Professor in 1899, when the principal Universities of the Old and New World sent their most distinguished savants to do honor to the event. His researches into optics and the spectrum analysis, his investigation into the variation of gravity over the Earth's surface, and his enunciation of the laws of fluorescence, placed him in the front rank of nineteenth century scientists. His papers on these and many other subjects are pronounced to be 'perfect in form and unassailable in accuracy.' He died at the ripe old age of 83."

"At the ripe age of 93 there has just died Mr. JAMES GLAISHER, F.R.S., for many years Superintendent of the Magnetical and Meteorological Department of the Royal Observatory, Greenwich, and a scientist of no mean attainments. His special study was meteorology, and in the pursuit of his investigations he made the famous seven-mile balloon ascent with the late Mr. HENRY COXWELL, when both aeronauts narrowly escaped with their lives. Mr. GLAISHER was born in London in April, 1809, and was barely 20 years old when he received an appointment in connection with the Ordnance Survey of Ireland. He made close observations respecting the formation and the colors of clouds, subsequently publishing a book on the subject. In 1833 he became an assistant at Cambridge Observatory, and three years later assistant in the Astronomical Department of the Royal Observatory at Greenwich, while in 1840 he was appointed superintendent of the newly formed Magnetic and Meteorological Department at Greenwich. That post he continued to hold until his retirement from the public service 34 years later. Among other things he did in this position was to begin, in 1841, the publication of those quarterly and annual reports on meteorology which have been regularly issued by the Registrar-General ever since. Mr. GLAISHER wrote more than 100 books and papers on astronomy, meteorology, and the theory of numbers."

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, MARCH 28, 1903, AT 7:30 P.M.

President **Perrine** presided. A quorum was present. The minutes of the last meeting were read and approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED MARCH 28, 1903.

Mr. Geo. A. Batchelder	Menlo Park, Cal.
Mr. H. C. Chesebrough	300 California St., S. F., Cal.
Dr. Russel Tracy Crawford	Students' Observatory, Berkeley, Cal.
Mr. Ralph Curtiss	Lick Observatory, Mt Hamilton, Cal.
Mr. E. A. Denicke	1000 Mason St., S. F., Cal.
Mr. R. H. E. Espey	Room 4, 4th floor Mills Building, S. F., Cal.
Dr. A. F. Gillihan	Students' Observatory, Berkeley, Cal.
Mr. H. T. S. Green	London, Paris & American Bank, S. F., Cal.
R Waldo Harrison	165 Clinton Ave , Jersey City, N. J.
Mr. Garrett W. McEnerney	Nevada Block, S. F., Cal.
Mr. James D. Phelan	Phelan Building, S F., Cal.
Mrs. E. T. Schild	1908 Broadway, S. F., Cal.
Dr. M. Schirman	Rooms 426–427, Emma Spreckels Building, S. F., Cal.
Mr. S. E. Slade	6 California St., S F., Cal.
Mr. A. B. Spreckels*	327 Market St., S. F., Cal.
Mr. Joel Stebbins	Lick Observatory, Mt Hamilton, Cal
Mr F. W. Van Sicklen	1831 Central Ave., Alameda, Cal.
Mr. J. H. G. Wolf	92 Flood Building, S. F., Cal.

REPORT OF THE LIBRARY COMMITTEE.

The Library Committee presented its report, as follows, and the report was accepted and filed:—

San Francisco, Cal., March 28, 1903.

To the Board of Directors of the Astronomical Society of the Pacific:—

We, the undersigned Committee of the Society's Library, report as follows:—

Since the last written report, two years ago, several changes have been made in the Library; a set of shelves and a chest of drawers have been added to the equipment, the books and pamphlets have been rearranged, many incomplete volumes and sets completed, the accessions book and the card catalogue checked up, and a good start made toward the preparation of the catalogue authorized by the Board of Directors at the meeting of November 30, 1902.

By binding, purchase, and gift the number of volumes in the accessions book has been increased in the last two years from 1,144 to 1,258. There are also about forty volumes at the bindery, which makes a total of 1,300 bound volumes in the Society's Library.

The expenditures from the Alexander Montgomery Library Fund may be found in the Treasurer's report.

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* Signifies life membership

The Committee wishes to express its indebtedness to Miss ADELAIDE HOBE, a member of the Society, who kindly spent several days during the Christmas holidays aiding the Committee in rearranging the books and in checking up the accessions book and the card catalogue.

Respectfully submitted,

SIDNEY D. TOWNLEY, *Librarian.*
ROSE O'HALLORAN.

The following resolutions were adopted:—

Resolved, That the sum of $5,000, constituting the bequest to the Society by the late Mr. JOHN DOLBEER be transferred from the General Fund to a separate fund, to be known as the JOHN DOLBEER FUND of the Astronomical Society of the Pacific.

It was, upon motion by the Treasurer,

Resolved, That the funds of the Society, with the exception of the General Fund, be placed under the immediate care of the Finance Committee, and that moneys belonging to such funds shall be withdrawn only upon orders or receipts signed by at least a majority of the members of said Finance Committee, and that a copy of this resolution, duly certified by the President and Secretary, be delivered to the banks holding such deposits.

It was, upon motion by Mr. CUSHING,

Resolved, That the Finance Committee be empowered to invest the funds of the Society, upon the consent of the President, in such first-class bonds as they may deem advisable.

Resolved, That the dates of issue of the *Publications* be changed from the 1st to the 10th of the months of February, April, June, August, October, and December.

AMENDMENT TO THE BY-LAWS.

The following amendment to the By-Laws was duly adopted by the consenting votes of nine Directors, namely:—

Messrs PERRINE, LEUSCHNER, CUSHING, BABCOCK, AITKEN, CAMPBELL, PIERSON, MOLERA, ZIEL.

ARTICLE IX.

The annual meeting of this Society shall be held on the last Saturday in March, at 8 o'clock P. M., at the rooms of the Society in San Francisco; and meetings shall be held for the ordinary transactions and purposes of the Society, as follows:—

Meetings shall be held in the Library of the Lick Observatory, Mount Hamilton, at a suitable hour on the last Saturdays of June and August; and meetings shall be held in the rooms of the Society, in San Francisco, at 8 o'clock P. M., on the last Saturdays of January, March, and November.

A special meeting may be called by the President, or, in his absence or disability, by one of the Vice-Presidents, or, in the absence or disability of the President and the Vice-Presidents, by the Secretary, on the written requisition of ten active or life members; and the object of such meeting shall be stated in the notice by which it is called.

The annual election shall be held on the day of the annual meeting, between the hours of 8:15 and 9 P. M.

No member shall be permitted to vote at any meeting of the Society who has not paid all his dues for past and current years. There shall be no voting by proxy.

Adjourned.

MINUTES OF THE FIFTEENTH ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE LECTURE HALL OF THE CALIFORNIA ACADEMY OF SCIENCES, MARCH 28, 1903, AT 8 P. M.

The meeting was called to order by President PERRINE. A quorum was present. The minutes of the last meeting were approved. The Secretary read the names of new members duly elected at the Directors' meeting.

The following papers were presented:—

1. Address of the retiring President of the Society, by C. D. PERRINE.
2. Reports of Committees; on Nominations; on the Comet Medal; on the Library; on Auditing; and Annual Report of the Treasurer.
3. The D. O. Mills Expedition to Chile, by W. W. CAMPBELL.
4. Astronomical Observations at Odder. Denmark, in 1902, by TORVALD KÖHL.
5. The Parallax of *Delta Equulei*, by W. J. HUSSEY.
6. Observations of Variable Stars, by Miss ROSE O'HALLORAN.
7. The Orbit of *Epsilon Hydræ*, AB., by R. G. AITKEN.
8. Planetary Phenomena for May and June, 1903, by MALCOLM MCNEILL.

The Committee on Nominations reported a list of names proposed for election as Directors, as follows: Messrs. R. G. AITKEN, CHAS. BURCKHALTER, W. W. CAMPBELL, WM. H. CROCKER, CHAS S. CUSHING, O. VON GELDERN, A. O. LEUSCHNER, E. J. MOLERA, WM. M. PIERSON, S. D. TOWNLEY, F. R. ZIEL.

For Committee on Publication: Messrs. R. G. AITKEN (Chairman), FRANK SCHLESINGER, S. D. TOWNLEY.

Messrs. BABCOCK and VON GELDERN were appointed as tellers. The polls were open from 8:15 to 9 P. M., and the persons above named were duly elected to serve for the ensuing year.

REPORT OF THE COMMITTEE ON THE DONOHOE COMET-MEDAL.

Submitted March 28, 1903.

This report relates to the Calendar year 1902. The Comets of 1902 have been:—

Comet *a* (unexpected comet) discovered by W. R. BROOKS at Geneva, N. Y., on April 14th.

Comet *b* (unexpected comet) discovered by C. D. PERRINE at the Lick Observatory on September 1st.

Comet *c* (unexpected comet) reported by JOHN GRIGG of Thames, New Zealand, as having been seen by him first on July 23d. This comet appears to have escaped detection by other observers.

Comet *d* (unexpected comet) discovered by M. GIACOBINI at Nice on December 2d.

In accordance with the statutes, Donohoe Comet-Medals have been awarded to the discoverers of Comets *a*, *b*, and *d*.

W. W. CAMPBELL,
CHAS. BURCKHALTER,
WM. M. PIERSON,
Committee on the Donohoe Comet-Medal.

The Treasurer submitted his Annual Report as follows:—

ANNUAL STATEMENT OF THE RECEIPTS AND EXPENDITURES OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE FISCAL YEAR ENDING MARCH 28, 1903.

GENERAL FUND.

Receipts. (March 30, 1902, to December 31, 1902.)

1902, March 30th. Cash Balance			$77 27
Received from dues for 1892 and previous years	$206 62		
" " " " 1903	40 00		
" " Life membership fee	50 00	$296 62	
" " sale of publications		72 58	
" " " " stationery		1 00	
" " Bruce Medal Fund (loan of March 8, 1900, returned)		81 62	
" " Contribution by Mr. Wm. Alvord		100 00	
" " " " " Wm. M. Pierson		475 00	
		$1,026 82	
Less transfer to Life Membership Fund		50 00	976 82
			$1,054 09

Expenditures. (March 30, 1902, to December 31, 1902.)

For Publications: printing Vol. XIV	$566 15		
illustrations	16 45	$582 60	
Stationery and printing		81 30	
Postages		56 41	
Rent		135 00	
Salary Secretary-Treasurer		135 00	
Expressages		8 85	
Telephone		50	
Janitor		4 00	
Gas		3 90	
Insurance premiums		22 75	
Carpenter and locksmith		1 00	
Lecturer's traveling expenses		12 50	
Lantern at lecture		8 00	1,051 81
1902, December 31st. Cash Balance			$2 28

Receipts. (January 1 to March 28, 1903.)

Received from dues for 1903	$552 02		
" " " " previous years	90 00	$642 02	
" " Security Savings Bank (interest)		17	
" " Life Membership Fund (interest)		53 76	
Bequest received from Estate of John Dolbeer		5,000 00	5,695 95
			$5,698 23

Expenditures. (January 1 to March 28, 1903).

For Publications: printing No. 88 of Vol. XV	$126 55	
Stationery and printing	54 00	
Postages	10 60	
Rent	45 00	
Salary Secretary-Treasurer	45 00	
Expressages	25	
Janitor	1 00	
Gas	1 00	
Bank exchanges	15	283 55
1903, March 28th. Cash Balance		$5,414 68

LIFE MEMBERSHIP FUND.

1902, March 30th. Cash Balance	$1,653 95
Received from General Fund	50 00
Interest for 1902	53 76
	$1,757 71
Less transfer to General Fund (interest)	53 76
1903, March 28th. Cash Balance	$1,703 95

DONOHOE COMET-MEDAL FUND.

1902, March 30th. Cash Balance	$685 47
Interest for 1902	22 11
	$707 58
Less engraving medals Nos. 41 and 42	2 00
1903, March 28th. Cash Balance	$705 58

BRUCE MEDAL FUND.

1902, March 30th. Cash Balance		$2,554 07
Interest for 1902		76 84
		$2,630 91
Less remittance to A. Dubois, balance of fourth award	$ 50	
" advance of March 8, 1900, returned to General Fund	81 62	82 12
1903, March 28th. Cash Balance		$2,548 79

ALEXANDER MONTGOMERY LIBRARY FUND.

1902, March 30th. Cash Balance		$1,559 39
Interest for 1902		49 26
		$1,608 65
Less expenditures:		
Mueller: Photometrie der Gestirne, Scheiner: Photographie der Gestirne,	$10 62	
Byrd: Laboratory Manual in Astronomy, Comstock: Method of Least Squares, Doolittle: Treatise on Practical Astronomy, Morton: Heroes of Science, Dreyer: Tycho Brahe, Lodge: Pioneers of Science, Comstock: Textbook of Astronomy, Howe: Elements of Descriptive Astronomy, Todd: New Astronomy, Richards: Navigation and Nautical Astronomy, Newcomb: The Stars, Jacoby: Practical Talks by an Astronomer, Moulton: Celestial Mechanics,	17 90	
Brickerton: Romance of the Earth, " " " " Heavens,	4 75	
Valentiner: Handwoerterbuch der Astronomie (4 vols.)	23 34	
Hicks-Judd Co., binding	29 40	
Astronomical Journal, Vol. 23	5 00	
Popular Astronomy, Vol. 11	2 50	93 51
1903, March 28th. Cash Balance		$1,515 14

FUNDS.

Balances on Deposit as follows:

General Fund:		
with Donohoe-Kelly Banking Co	$ 414 68	
" Union Trust Co.	2,500 00	
" Mutual Savings Bank	2,500 00	$5,414 68
Life Membership Fund:		
with San Francisco Savings Union	$653 95	
" German Savings and Loan Society	450 00	
" Hibernia Savings and Loan Society	600 00	$1,703 95
Donohoe Comet-Medal Fund:		
with San Francisco Savings Union	$221 45	
" German Savings and Loan Society	237 68	
" Hibernia Savings and Loan Society	246 45	$705 58
Alexander Montgomery Library Fund:		
with San Francisco Savings Union	$439 84	
" German Savings and Loan Society	424 48	
" Hibernia Savings and Loan Society	650 82	$1,515 14
Bruce Medal Fund:		
with San Francisco Savings Union	$1,268 83	
" Security Savings Bank	638 37	
" German Savings and Loan Society	641 59	$2,548 79
		$11,888 14

San Francisco, March 28, 1903.

F. R. ZIEL, *Treasurer.*

Examined and found correct.

Chas. S. Cushing, }
L. H. Pierson, } *Auditing Committee.*

The report was, on motion, accepted and filed.

The Committee appointed to audit the Treasurer's accounts reported as follows, and the report was, on motion, accepted and adopted:—

San Francisco, Cal., March 28, 1903.

To the President and Members of the Astronomical Society of the Pacific:

Gentlemen — Your committee appointed to audit the accounts of the Treasurer for the fiscal year ending March 28, 1903, has, after a careful examination, found the same to be correct.

Respectfully submitted,

Chas. S. Cushing, }
L. H. Pierson, } *Committee.*

The President then read his annual address.

Professor Leuschner read Professor Hussey's paper on the Parallax of *Delta Equulei;* and Mr. Babcock read Professor Campbell's paper on the D. O. Mills Expedition to Chile. President Perrine then replied to questions put by members of the Society.

The following resolution was, on motion, adopted:—

Resolved, That all the acts appearing in the minutes of the meetings of the Board of Directors of this Society, as having been done by said Board during the past fiscal year, are here now, by this Society, approved and confirmed.

Adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, MARCH 28, 1903, AT 9:30 P.M.

The new Board of Directors was called to order by Mr. BURCKHALTER. A quorum was present. The minutes of the last meeting were approved.

The business in hand being the election of officers and committees for the ensuing year, the following officers and committees, having received a majority of the votes cast, were duly elected:—

President: Mr. VON GELDERN.
First Vice President: Mr. S. D. TOWNLEY.
Second Vice-President: Mr. W. W. CAMPBELL.
Third Vice-President: Mr. CHAS. S. CUSHING.
Secretaries: Messrs. R. G. AITKEN and F. R. ZIEL.
Treasurer: Mr. F. R. ZIEL.

Committee on the Comet-Medal: Messrs. CAMPBELL (*ex-officio*), PIERSON, and BURCKHALTER.

Library Committee: Messrs. TOWNLEY, RICHARDSON, Miss O'HALLORAN. Mr. TOWNLEY was appointed Librarian.

Finance Committee: Messrs. PIERSON, CUSHING, LEUSCHNER.

The Committee on Publication is composed of: Messrs. R. G. AITKEN (*Chairman*), FRANK SCHLESINGER, S. D. TOWNLEY.

The Board of Directors is composed of: Messrs. AITKEN, BURCKHALTER, CAMPBELL, CROCKER, CUSHING, VON GELDERN, LEUSCHNER, MOLERA, PIERSON, TOWNLEY, and ZIEL.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. von Geldern	*President*
Mr. S. D. Townley	*First Vice-President*
Mr. W. W. Campbell	*Second Vice-President*
Mr. Chas. S. Cushing	*Third Vice-President*
Mr. R. G. Aitken Mr. F. R. Ziel	*Secretaries*
Mr. F. R. Ziel	*Treasurer*

Board of Directors—Messrs. Aitken, Burckhalter, Campbell, Cushing, Leuschner, Molera, Crocker, von Geldern, Pierson, Townley, Ziel.

Finance Committee—Messrs. Pierson, Cushing, Leuschner.

Committee on Publication—Messrs. Aitken, Schlesinger, Townley.

Library Committee—Mr. Townley (*Librarian*). Richardson, O'Halloran.

Committee on the Comet-Medal—Messrs. Campbell (*ex-officio*), Pierson, Burckhalter,

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Felipe Valle.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

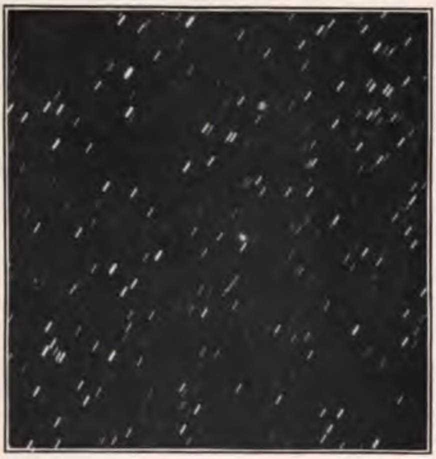
Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

THE [illegible]

THE NEW YORK
PUBLIC LIBRARY

ASTOR, LENOX AND
TILDEN FOUNDATIONS



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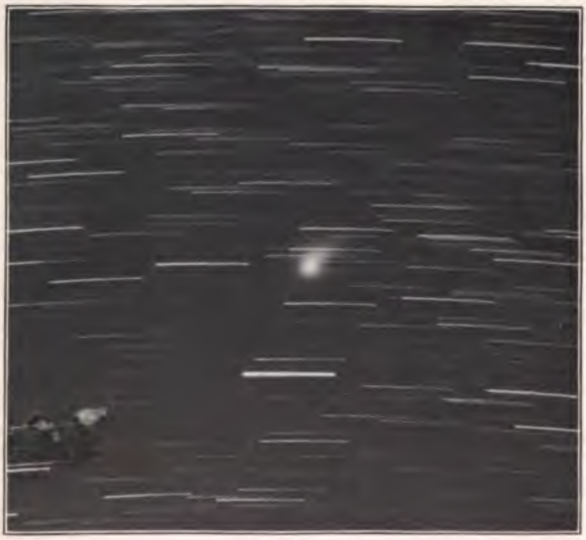


1902. Sept. 30

1902. Oct. 31

COMET b, 1902 (PERRINE)

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XV. SAN FRANCISCO, CALIFORNIA, JUNE 10, 1903. NO. 90.

PHOTOGRAPHIC OBSERVATIONS OF COMET *b* 1902 (PERRINE).

BY R. H. CURTISS.

At the time of its discovery, September 1, 1902, this comet was of the 9th magnitude, with a fairly sharp nucleus of magnitude 10½ or 11. As the preliminary orbit predicted an interesting career for the visitor, it was decided to make a series of photographs at intervals, depending upon the degree of activity developed.

For this work the Pierson (Dallmeyer) camera of 15^{cm} aperture and 82.6^{cm} equivalent focal length seemed best adapted, the more so because of its superior driving and guiding facilities. This instrument is mounted in parallel with the Floyd telescope of 12.5^{cm} aperture and 200^{cm} focal length, and the combination is carried by a Warner & Swasey mounting. The Floyd is provided with a guiding eye-piece with adjustable electrical illumination. Though of rather high power, this eye-piece has been found particularly useful in guiding on faint objects. In the case of this comet, the intersection of two fine cross-wires was the reference-point in guiding.

As the comet brightened, it was decided to make simultaneous large-scale photographs with the Floyd telescope, which may be adapted for photographic purposes by reversing the crown-lens. The focal length is then 178^{cm}. An additional telescope of 7^{cm} aperture and 95^{cm} focal length was added to the combination, the guiding arrangements being transferred to this smaller instrument.

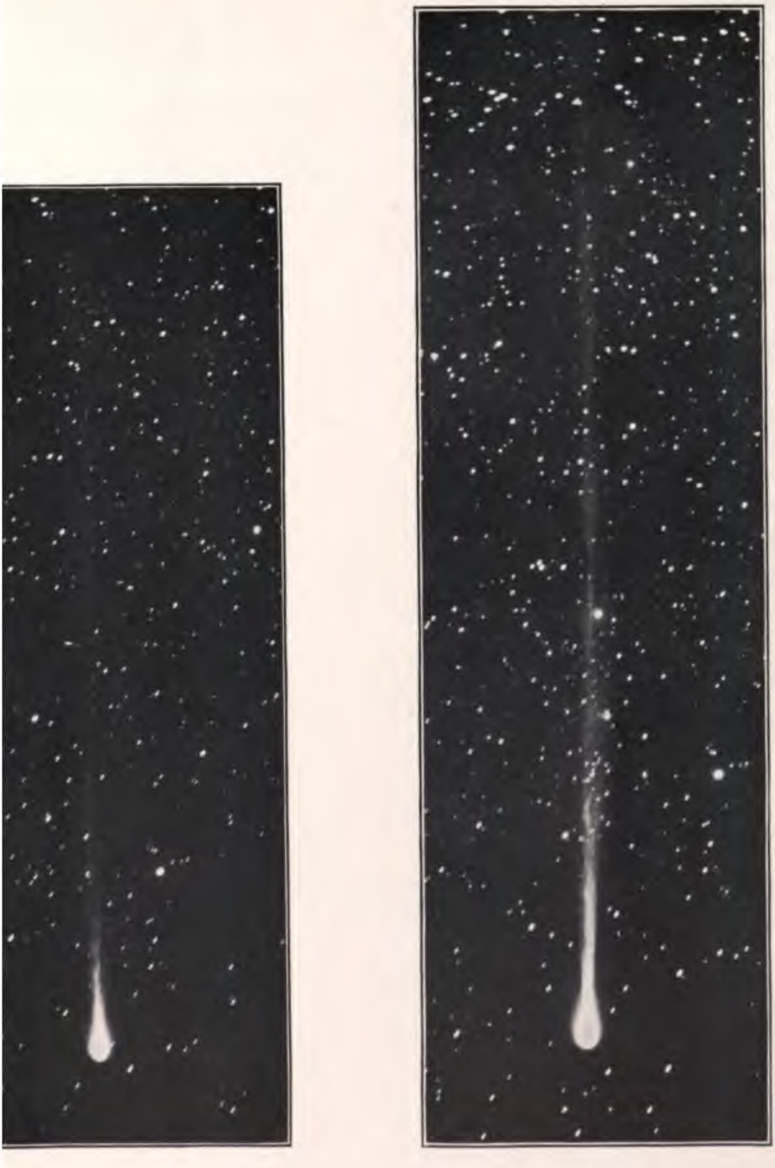
The scale of the negatives reproduced is 0°.693 per cm at the center of plate, and, at the distance (d) in cm from the center, the scale value is $\frac{4730}{6820+d^2}$ degrees per cm. In all the copies the scale of the original has been preserved.

In all, eighteen exposures were made in a total of fifty hours. Eighteen negatives were secured with the Pierson camera and fourteen with the Floyd. The exposure on any night was as long as circumstances would allow, ranging from 25 minutes to 6 hours.

Owing to uncertainties incident to varying sky and unequal exposures, and because of the difficulty of assigning any definite termination to a gradually fading comet-tail, a detailed study of the changes in the length of the tail is perhaps of little interest. The accompanying cuts will illustrate in a general way the nature of such changes. With an exposure of four hours on September 3d, the length of the tail recorded is 3^{mm}; on September 25th, 2^{cm}. On October 7th the longer tail can be traced for 7^{cm}, and finally, in the latter part of October, it runs clearly to the edge of the plate, a distance of 16^{cm}, or 11°, through regions blurred by aberration. On November 1st, the tail of this comet was certainly more than sixteen million miles long.

The changes in structure of the tail between successive exposures are most interesting on the plates after October 7th. In the case of the earlier negatives no clear details are to be expected, on account of the faintness of the tail and the changes in its form during the long exposures. The secondary tail is clearly seen on the first negative of long exposure (September 3d). The primary tail appears very nearly straight on all the plates while the other is curved and much shorter than the straight tail, though nearly as bright. On the plate of October 7th, the secondary tail is clearly identified for the last time.

The negatives from October 25th to November 2d, inclusive, show much interesting detail. The comet at that time was within a month of perihelion passage, and therefore in very active condition. With the purpose of determining the velocity of motion of any given point in the tail with reference to the head, I have tried to identify any condensation or configuration on successive nights, but so complete was the change in a day that nothing of the kind was possible.



1902. Nov. 1

1902. Nov. 2

COMET b, 1902 (PERRINE)

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The plate of October 25th shows three main streamers, of which the central one is brightest and longest. The tail splits up into two streams close to the head. The fainter one is straight, while the brighter one curves away a little and divides into two straight streamers. On the following night the fainter streamer has nearly disappeared. No other streamers appear, but the main tail suddenly spreads about 3^{cm}, or 2°, from the head to six times its width near the coma, and a rift appears in the center of this thicker portion. On October 27th several new streamers appear. On the negative of October 31st as many as eight distinct streamers can be seen. They extend about 7^{cm} from the head, while the main tail continues 16^{cm} to the edge of the plate. On the following night these streamers have faded, while on November 2d there is but one connected with the main tail, which has straightened out to a narrow bright streamer of varying width.

On the earlier negatives, the nucleus is sharp and clearly defined. It is surrounded with a layer of nebulous matter. As the comet approaches the Sun, the nucleus spreads, and the layer of nebulous matter seems to diminish in thickness while a heavy fan-shaped spray appears on the side of the head away from the Sun.

A table of exposures appears below. After September 25th, negatives were made simultaneously with the Pierson and Floyd cameras. The times of beginning and ending are expressed in Pacific standard time:—

Date.	Beginning.	End.
1902.		
September 1...	12.40	13.05
3...	12.10	16.33
10...	12.08	16.10
25...	8.10	12.50
30...	11.42	16.42
October 3...	9.15	15.00
4...	9.26	15.25
7...	10.05	14.25
25...	7.00	8.45
1902.		
October 26...	6.45	8.35
27...	6.32	8.23
28...	6.25	8.13
29...	6.27	8.07
31...	6.19	7.54
November 1...	6.25	7.40
2...	6.25	7.32
4...	6.35	7.15
5...	6.37	7.00

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1903.

By **Malcolm McNeill.**

PHASES OF THE MOON, PACIFIC TIME.

First Quarter, July	1,	$1^h\ 2^m$ P.M.	Full Moon, Aug.	8,	$12^h\ 54^m$ A.M.
Full Moon, "	9,	9 43 A.M.	Last Quarter, "	15,	9 22 P.M.
Last Quarter, "	17,	11 24 A.M.	New Moon, "	22,	11 31 A.M.
New Moon, "	24,	4 46 A.M.	First Quarter, "	29,	12 34 P.M.
First Quarter, "	30,	11 15 P.M.			

The Earth is in aphelion on the evening of July 2d.

Mercury is not in very favorable position for naked-eye view during July and August. At the beginning of July it is a morning star, having passed greatest west elongation late in June, but the interval between the rising of the planet and sunrise is only a little more than one hour. The interval remains as great as one hour until about the middle of the month, and it is possible that the planet may be seen in especially good weather. After the middle of the month the planet rapidly approaches the Sun, and passes superior conjunction July 26th. Throughout August it is an evening star, and toward the close of the month it is nearly at its greatest east elongation, but the relatively great southern declination of the planet allows it to remain above the horizon less than an hour after sunset, and thus makes the conditions for visibility decidedly poor.

Venus is still an evening star, and reaches its greatest east elongation, 45° 30′, on July 9th; but after that its distance from the Sun diminishes very rapidly, and by the end of August it has nearly reached inferior conjunction. On July 1st it sets about $2^h\ 35^m$ after sunset, on August 1st, $1^h\ 45^m$ after, and on September 1st, only 22^m later. The planet is now in that part of its orbit farthest south of the ecliptic, and this contributes materially toward diminishing the interval between the setting of the Sun and of the planet. *Venus* will, however, come to its greatest brightness on August 12th, and for some weeks before and after that time will be visible in full sunlight, if one knows where to look for it. *Mercury* and *Venus* are in conjunction on August 28th, with *Venus* a little more than 6° south of *Mercury*.

Mars is still in fair position for evening observation in the western sky. On July 1st it sets a little before midnight and two months later, on September 1st, it sets shortly after 9 o'clock. Its distance from us in millions of miles increases from 104, on July 1st, to 122, on August 1st, and 139, on September 1st, and in consequence its brightness diminishes more than fifty per cent during the interval; but it will still be bright enough to be rather conspicuous among the stars, and it will not be at all difficult to identify. Its motion among the stars during July and August is about 32° eastward and 13° southward from the western part of the constellation *Virgo* into *Libra*. On July 23rd it passes about three diameters of the Moon north of *Spica*, *α Virginis*. On July 1st it is in conjunction with the Moon, and on the evening of that day the Moon will pass just south of the planet. The planet will be occulted in countries farther south than the United States, and perhaps in the extreme southern parts of this country.

Jupiter is moving around toward a position favorable for evening observation. It rises shortly after 11 P. M. on July 1st, and by the end of August shortly after seven. It is in the constellation *Pisces*, and moves slowly eastward, about 15′, until July 14th. It then begins to move westward, and by the end of August this retrograde motion amounts to about 3°. In its retrograde motion it follows a path a fraction of a degree south of its eastward path, and at the end of August its position is about the same as it was at the end of May.

Saturn is in good position for observation. It comes to opposition with the Sun on July 30th, and is consequently above the horizon nearly the entire night throughout the two months. It is in the constellation *Capricorn*, and moves about 5° westward during July and August. Both *Saturn* and *Jupiter* are in a region in which there are few bright stars.

Uranus is above the horizon until late at night, not setting until about 3:30 on July 1st, and shortly after 11 on September 1st. It moves westward until the end of August a little more than 1° in *Ophiuchus* between *Scorpio* and *Sagittarius*, but no bright star is near enough to afford an easy identification.

Neptune passed conjunction with the Sun late in June, and is now a morning star, but until August it remains too near the Sun to be easily seen even with a good telescope.

August is the month for the *Perseid* meteors, and the watcher for them will be able to see a good many during any clear night, especially during the second week of the month.

AN APPLICATION OF THE CROSSLEY REFLECTOR OF THE LICK OBSERVATORY TO THE STUDY OF VERY FAINT SPECTRA.*

By H. K. Palmer.

While engaged in photographing the brighter nebulæ with the Crossley reflector, the late Professor Keeler noted the great relative photographic brightness of the central stars in the ring nebulæ in *Lyra* and *Cygnus*—a fact indicating that the spectra of these stars contain an unduly large proportion of actinic rays. He tried to examine their spectra, both with a direct-vision spectroscope and with a prism held in the path of the rays, but in neither case was the spectrum bright enough to be seen. He therefore decided to construct a spectrograph for the study of these objects.

Such an instrument, to preserve and utilize the enormous advantages of the silver-on-glass reflecting telescope for work in the violet and ultra-violet regions, called for a design radically different from those of conventional spectroscopes. It would evidently be difficult for a star near the limits of vision to be centered and kept upon a narrow slit; the method of guiding by means of a reflecting slit would not answer; and it would be important to avoid the usual losses due to a slit. The instrument as originally designed consisted, in outline, of a 50° quartz prism with circular aperture of 27^{mm}, placed directly in the converging beam of light from the great mirror, at a distance of 15^{cm} inside the focus; of a plate-holder suitably placed; and of a guiding eye-piece working on the same principle as that employed in ordinary nebular photography.

Director Keeler had thought that by placing the prism approximately at minimum deviation for the ray coinciding with the collimation axis, the confusion in the image, due to the very large angle of the cone of incidental light, would be so slight as not to interfere with the qualitative purposes of the instrument; especially since the dispersion would be small—only 3^{mm} from λ 350 to λ 500. It should be said, however, that he had doubts as to the success of this plan, but felt that it would be well worth a trial.

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* Abstract from Lick Observatory Bulletin No. 31.

The spectograph was constructed by the observatory instrument-maker. It was completed on the day Professor KEELER left Mt. Hamilton for the last time, about a fortnight before his death.

A few weeks thereafter Dr. CAMPBELL and I tried the spectrograph, and found that the beam of light could not be brought to a focus. On account of the approaching opposition of *Eros,* and the plans for completing, if possible, Professor KEELER's program of photographing the brighter nebulæ during the following spring, the instrument was set aside until April, 1901.

Director CAMPBELL then asked me to design such changes in the instrument as would permit the insertion of a double concave quartz lens immediately in front of the prism, and of a double convex similar lens immediately behind the prism to receive the refracted rays and form the image on the sensitive plate. The lenses were constructed by the John A. Brashear Co., from constants supplied by Professor WADSWORTH. These additions to the optical train necessitated several changes in the support of the plate, in the guiding fixtures, etc. The alterations were completed by the instrument-maker on June 3d, and to me was assigned the duty of testing its capabilities.

It is only possible here to give a brief summary of the observations and the conclusions to which they have led, referring the reader to the original paper in Lick Observatory *Bulletin* No. 34 for the details, as well as for the full description, of the apparatus, its adjustments, and the method of observing.

As soon as the spectrograph was completed and adjusted, photographs were taken of the spectra of various objects to find out for what work an instrument of this kind is best adapted; and to determine its limitations. It is evident that, because of the small dispersion, it cannot as a rule be used to advantage on the dark-line spectra, but some stars have been photographed with dark bands, broad enough to show. This limits it very largely to bright-line spectra, though it has great value for determining the nature of very faint spectra of all kinds. Moreover, since there is no slit, the object must not be so large that the various monochromatic images will overlap too much, and this condition confines the field to objects no larger than planetary nebulæ.

Large numbers of objects having various spectral types promised to yield valuable results; but on account of the limited time at my command, my program was confined, with the director's approval, to comparatively few objects. These included:—

(*a*) Such planetary nebulæ as were in observing position, both for purposes of comparison with results reached by observers using other instruments, and in the hope of discovering new features in the ultra-violet region. It was not expected that results obtained in the $H\epsilon$—$H\beta$ region of bright objects, by observers using large telescopes and powerful spectroscopes, would be surpassed or even equaled, on account of the feeble dispersion of this instrument.

(*b*) Such new stars as were in observing position.

(*c*) The central star in the ring nebula in *Lyra*, and other similar stars and stellar nuclei.

(*d*) A few Wolf-Rayet stars.

Altogether, twenty-one nebular spectra were photographed by me between June and September, 1901. After my departure, Mr. JOEL STEBBINS, Fellow in the Lick Observatory, kindly secured for me with the same instrument some very good spectrograms of *Nova Aurigæ*, *Nova Persei*, and a Wolf-Rayet star.

Examination of these spectrograms shows that in general the intensity of the continuous spectrum of the nebulæ has a minimum between $H\delta$ and $H\gamma$. This fact is confirmed by nearly all the negatives, and is too general a characteristic to be passed without notice. It seemed hardly possible that the spectrum of the nucleus, to which it was supposed that this belonged, should have an absorption band at this place, and another explanation was sought. This was found by plotting Dr. CAMPBELL's observations of G. C. 4390 on the same scale, and comparing the result with the spectra obtained with the slitless spectrograph. His observations were made with a large spectroscope attached to the 36-inch refractor. Inspection of this spectrum showed that he found the bright lines much fewer in the region where the continuous spectrum is weak in the spectrograms taken with the small instrument. His observations of N. G. C. 7027 give the same results. From this it seems safe to infer that the apparently greater relative strength of my spectrograms in the *H*γ—*H*β region is largely due to the presence of many faint overlapping bright lines, whereas, in the region *H*δ—*H*γ fewer bright lines exist. A further support of this theory is afforded by nebulæ N. G. C. 6826 and N. G. C. 6891, each of which has a stellar nucleus. In each case the spectrum of the necleus has an almost uniform intensity throughout its entire extent.

One of the marked advantages of the reflector and quartz prism and lenses over the great refractor and glass optical train in spectrum observations is revealed by this comparison. Even in the favorable nebula G. C. 4390, CAMPBELL's results stop at *H*ζ, whereas the slitless spectrograph record extends to about λ 337.

One of the principal purposes of this investigation was to determine the efficiency of the slitless quartz spectrograph attached to the Crossley reflector, for the photography of very faint spectra. Its power in this respect is surprisingly great. It is well illustrated in the case of *Nova Cygni.* The visual magnitude of this star was estimated by Professor BARNARD in 1901 to be 15.5. My four-hour exposure, with fair following and focus, recorded its continuous spectrum in good strength, well up into the ultra-violet. The character of the spectrum could have been determined had the image been considerably less intense. This spectrum may be relatively stronger in the photographic regions than ordinary stellar spectra, though the spectra of many adjacent 15th-magnitude stars are recorded satisfactorily on the same plate. It would be perfectly practicable to carry the exposures up to ten hours or more; the guiding could be more accurate, now that the principal sources of the irregularity in diurnal motion have been removed;

and perhaps the more stable new telescope mounting will eliminate the present unfortunate changes in the focus during exposures. Considering these facts, I am reasonably confident that this instrument can record the continuous spectrum of the faintest star visible in the 36-inch telescope under the corresponding atmospheric conditions. Further, in the case of stellar nebulæ, etc., whose spectra contain well-defined bright lines, I do not doubt that the instrument will record the principal bright lines of objects too faint to be seen in our most powerful telescopes.

It is only for work on very faint spectra that this spectrograph is efficient. Its dispersive power is very low, and it should seldom be used on spectra, or on those portions of spectra bright enough to be recorded by relatively longer exposures with instruments giving greater dispersion.

For qualitative studies of general spectral features, this spectrograph is efficient on all spectra, whether continuous or bright line; but for quantitative results its usefulness is limited largely to small and faint bright-line spectra.

For most of the objects observed, a 60° prism, and for some of the objects two 60° prisms would have been an improvement over the present 50° prism; requiring, of course, the reconstruction of the instrument.

For some of the stellar bright-line objects a convex lens of twice the present lens's focal length would have had an advantage in separating close lines on the photographic plate, permitting at the same time more accurate determinations of wave-lengths. This would probably alter the character of the field of the combination somewhat.

It is possible that a similar instrument on twice the linear scale, *i. e.*, with lenses and prism having 50^{mm} apertures,—with perhaps a 60° prism,—would be efficient and practicable for the objects of medium brightness on my list.

New nebular lines at λ 337 and λ 345 were discovered. These lines were later found to exist in the spectrum of *Nova Persei*, from the plate taken October 14, 1901. The nebular character of the *Nova* spectrum is thus established for the extreme ultraviolet region, as had previously been done for the other regions.

The spectrum of *Nova Cygni*, which in 1876 was of the usual "new-star" type, and later changed into the nebular type, has now become continuous, with no signs of bright lines.

The bright lines in the nebular spectrum of *Nova Aurigæ* are now relatively faint, and the spectrum appears to be approaching the continuous type.

These complete and astonishingly rapid changes of spectral types observed in the cases of *Nova Cygni* and *Nova Aurigæ,*—and likewise those observed in *Nova Normæ, Nova Sagittarii, Nova Persei,* etc.,—leave little doubt that the masses of these objects are small.

All the new stars of recent years should be reobserved with this spectrograph every year, to keep account of the progressive changes in their spectra. The importance of carrying out this plan can scarcely be overestimated.

The relative intensities of nebular and other bright lines, as well as of continuous spectra, are shown more accurately on the plates secured with this spectrograph than on those made with instruments absorbing the blue and violet very strongly.

The spectrum of the central star in the ring nebula in *Lyra* seems to be not of an unusual type, unless perhaps it contains a bright line near λ373. It is quite possible that the star is somewhat brighter photographically than visually; at least, photographic evidence is not opposed to this theory.

The great intensity of the λ373 ring in the ring nebula perhaps explains one point in nebular photography. Professor KEELER found that for most nebulæ an exposure of three hours gave the best results, whereas the best photograph of the ring nebula was obtained in ten minutes. While the ring nebula is brighter than the average bright nebula, this brief exposure of ten minutes is out of proportion to its visual brightness; but its radiation being mostly in the ultra-violet, it should have a somewhat greater photographic than visual brightness.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

CHANGES IN THE LICK OBSERVATORY STAFF.

Mr. HAROLD K. PALMER, Fellow in the Lick Observatory from July 1, 1898, to July 1, 1902, received the degree of Doctor of Philosophy from the University of California on May 14, 1903. Dr. PALMER holds the position of assistant in the Lick Observatory, with duties on the D. O. Mills Expedition to Chile. His thesis was on "An Application of the Crossley Reflector of the Lick Observatory to the Study of Very Faint Spectra."

Mr. JOEL STEBBINS, Fellow in the Lick Observatory from July 1, 1901, to July 1, 1903, received the degree of Doctor of Philosophy from the University of California on May 14, 1903. His thesis was on "The Spectrum of *Omicron Ceti*." Dr. STEBBINS has been appointed Instructor in Astronomy in the University of Illinois, in charge of the observatory and department.

The two theses referred to above will be printed soon as Lick Observatory *Bulletins*.

Mr. SEBASTIAN ALBRECHT of the University of Wisconsin has been appointed Fellow in the Lick Observatory for the year beginning May 1, 1903.

Mr. ELLIOT SMITH of the University of Minnesota has been appointed assistant in the Lick Observatory on the Carnegie Institution foundation, with duties in the Meridian Circle Department.

W. W. C.

MRS. HEARST'S GIFT TO LICK OBSERVATORY.

Mrs. Phebe A. Hearst, Regent of the University of California, has generously contributed to the funds of the Lick Observatory for the present year in continuation of her contribution for the year 1902. This gift is available for improving the equipment of the observatory at various points.

W. W. C.

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* Lick Astronomical Department of the University of California.

THE VARIABLE STAR 10, 1903 *LYRÆ*.

In No. 3857 of the *Astronomische Nachrichten,* Professor SEELIGER announces the discovery by Herr E. SILBERNAGEL of a star near the ring nebula in *Lyra* which is either variable or a *Nova*. The discovery was made from photographs taken at the Munich Observatory.

The position of this star was sufficiently near to the ring nebula to be on the negatives of the latter obtained by Professor KEELER with the Crossley reflector in 1899. Several plates were taken on July 12th, 13th and 14th, with exposures ranging from 30 seconds to two hours. On all the negatives with exposures of 30 minutes and over 10, 1903 *Lyræ* is visible as a star of 17th magnitude. There is no perceptible difference in brightness on these plates.

On April 18 and 20, 1903, two photographs were secured, with exposures of one hour each. These plates show this star as 12th magnitude.

Photographs of its spectrum were secured on April 18th, 20th, 21st, and 24th, with the small slitless-spectrograph, designed by Professor KEELER, attached to the Crossley reflector. These negatives show the hydrogen lines Hβ, Hγ, and Hδ to be bright, together with bright lines at λ 463 and λ 446. There is a very strong continuous spectrum extending from Hβ to above Hδ, and a weak spectrum in the ultra-violet.

A comparison of the spectrum of this star with that of *Nova Geminorum,* taken about the same time, shows that the hydrogen lines and λ 463 are of about the same relative intensity as in the *Nova;* while λ 446 and the continuous spectrum are very much stronger in the *Lyra* star.

A negative taken on an isochromatic plate shows, in addition, only the usual maximum at λ 570 which is characteristic of ordinary stars.

All of the facts at present known seem to indicate that the star is a variable of the well-known type in which the hydrogen lines are bright at the time of maximum, rather than a *Nova;* but some spectra of well-known variables of the type referred to will be photographed with the same instrument for purposes of comparison. C. D. P.

May 21, 1903.

A NEW STAR IN *GEMINI*.

A telegram received at the Lick Observatory on March 27th announced the discovery at Oxford, England, of a new star in the constellation *Gemini*.

Cloudy weather prevented observations here until the night of April 1st, when the star was found to be of about 8.5 magnitude. Notes on the photographic and spectrographic observations will be found on another page. In addition to these, micrometric measures were made connecting the *Nova* with five faint stars that are well placed for detecting any parallactic or proper motion it may have. It was the intention also to watch the brightness of the *Nova* closely, to see whether its light fluctuated as did that of *Nova Persei*. But cloudy weather interfered so much with this part of the program that no conclusions can be drawn from the observations. The star has gradually faded, however, and is now about 10th magnitude.

R. G. AITKEN.

May 21, 1903.

OBSERVATIONS OF *NOVA GEMINORUM* MADE WITH THE CROSSLEY REFLECTOR.*

Stormy weather prevented any observation of Turner's *Nova* until April 1st. On this date a photograph of the region was secured with an exposure of $1^h\ 46^m$, as well as a number of short exposures. No traces of any nebulosity were to be seen about the star, as in the case of *Nova Persei*. This result was not surprising, considering that in all probability the magnitude of the outburst was much less. These plates showed that *Nova Geminorum* was considerably brighter photographically than visually, notwithstanding its reddish color. At this time it was estimated as of 8½ visual magnitude. Short-exposure photographs were obtained on several succeeding nights for measurement.

The position of the *Nova*, as derived from two of these plates, using six catalogue stars, is as follows:—

1903.		R. A., 1903.0	Decl., 1903.0
April 1.	Plate No. 1298	$6^h\ 38^m\ 0^s.50$	+ 30° 2′ 28″.7
5.	" 1309	0.47	28 .7

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* Abstract of L. O. Bulletin, No. 37.

A number of the faint stars near the *Nova* were measured, and their positions follow:—

Star.	Magnitude.	Date, April 5. Plate No. 1310.		Date, April 8. Plate No. 1316.	
		p	s	p	s
		°	″	°	″
a	10	0.53	369.80	0·53	369.80
b	13	17.30	103.01	16.95	102.93
c	9·5	59.88	585·50	59·95	585·51
d	14	104.78	32.01	105.05	32.00
e	11	114.05	334 80	114 03	334 72
f	15	170.60	45·34	169.82	45·51
g	14	196.67	85.04	196.55	84.84
h	11	219.08	434.06	219.10	433·77
i	10	261.62	316.68	261.68	316.56
j	9 4	276.57	465.23	276.58	465.14
k	13	314·05	100.16	313.88	100 27

Star *j* is B. D. + 30° 1309.

The spectrum was photographed with the slitless spectrograph, with varying exposures and on several nights. The negatives show the usual bright lines which have been observed in other new stars in their early history, together with considerable continuous spectrum.

The following lines were measured on a plate taken on April 2, 1903:—

λ 486	$H\beta$	Bright.
462		Very bright.
446		Faint.
434	$H\gamma$	Very bright.
410	$H\delta$	“ “
397	$H\epsilon$	Bright.
389	$H\zeta$	Faint.
384	$H\eta$	Maximum.
374	$H\kappa$	“
350		“
335		End of spectrum.

The positions 384, 374, and 350 are the maximum of what appear to be bands with this low dispersion. The maxima at λ374 and λ350 are near the positions of two very bright lines in *Nova Persei*, which were observed by Dr. STEBBINS after the spectrum of that star had become nebular. Two lines at about the same wave-lengths were discovered in some of the well-known nebulæ by Dr. PALMER. In *Nova Geminorum* these lines are not yet developed, and are relatively very much weaker than they were in *Nova Persei.* As there are no early observations of this portion of the spectrum of *Nova Persei,* it is not possible to draw any conclusions as to these lines. It seems reasonable to expect, however, that they will develop along with the other nebular lines. C. D. PERRINE.

THE SPECTRUM OF *NOVA GEMINORUM.*

The spectrum of *Nova Geminorum* was observed, both visually and photographically at the Lick Observatory, with a spectroscope consisting of a single flint-prism mounted in conjunction with the collimator and camera of the regular Mills spectrograph. Unfortunately, unfavorable weather prevented any observations before April 1st, but after that date spectrograms were obtained on several evenings, both in the blue-violet region, and, by the use of isochromatic plates, in the visual part of the spectrum. The spectrum consists of broad, bright bands with some continuous spectrum. In its general features it resembles somewhat the spectrum of *Nova Persei* in March 1901, and also that in August of the following year; probably the star at its discovery had reached a stage in its development midway between those of *Nova Persei* at these two dates. Many of the bands coincide approximately with the lines of the hydrogen spectrum, and though a number of them could not be identified with hydrogen-lines, there was no certain trace of the so-called "nebular-lines," except the principal line λ 5007.

Between the date of the first spectrogram, April 2d, and that of the last, May 4th, the spectrum showed definite changes, but they are of such a nature that it cannot be said whether or not they indicate a progression toward the nebular type.

H. M. REESE.
H. D. CURTIS.

NOVA GEMINORUM.

The first opportunity of obtaining a long exposure on *Nova Geminorum* with the Crossley reflector, occurred on April 22d, 23d, and 24th, when a duration of 6^h 29^m was secured.

There are no indications of nebulosity about the *Nova* on this plate.

The spectrum was last photographed with the slitless spectrograph on May 11th. The star has faded nearly a magnitude in the interval, and the entire spectrum is weaker in consequence. There is a slight strengthening at about the position of the chief nebular line, and the bands at λ 373 and λ 350 seem to be slightly stronger. C. D. P.

May 21, 1903.

TWO NEW NAKED-EYE DOUBLE STARS.

The brighter stars of the northern heavens have been examined so many times with telescopes of all sizes that one hardly expects to find among them a double star that has not been observed before. Two such stars, however, belonging to two very different classes of double stars, have apparently hitherto eluded detection. The first is a star in *Coma Berenices,* rated at 6.0 magnitude in the Bonn D. M. On April 8, 1903, I examined this star with the 12-inch telescope and found that it was attended by a 12th-magnitude companion. One night's measure with the 36-inch telescope gives the position-angle 259°.7 and the distance 1″.35. As the principal star has an annual proper motion of 0″.22 in 148°.5, both the angle and distance should increase if the two stars are not physically connected.

The other star is in the constellation *Boötis,* not far from *Arcturus,* and is given as 5.9 magnitude in the Harvard Photometry. With the 12-inch telescope, on May 5, 1903, this star was seen to be a very close double. Measures on two nights with the 36-inch give: position-angle, 199°.8; distance, 0″.20; magnitudes, 6.5–6.5. The star has no proper motion.

The positions of these two stars for 1900.0 are, respectively: R. A., $13^h\ 28^m\ 4^s$; Decl., + 24° 52′; and R. A., $14^h\ 27^m\ 55^s$; Decl., + 27° 7′. R. G. AITKEN.

May 12, 1903.

CORRECTION TO THE AMERICAN EPHEMERIS FOR 1903.

In observing the satellites of *Uranus,* it has been my practice to guard against mistaking a small star for a satellite by computing the approximate positions of the satellites for

the time of observation from the times of greatest elongation and position-angle of the apparent apsides as given in the American Ephemeris. Until this year the agreement with observation has always been close—1° or 2°. But this year my observed angles are invariably 90° *smaller* than the computed ones. It would seem, therefore, that the times of greatest elongation as given in the American Ephemeris for 1903 are systematically in error by one fourth of the periods of the satellites.
R. G. AITKEN.

COMET *b*, 1903.

A telegram from Boston was received at the Lick Observatory on the evening of May 2d, announcing that a comet had been discovered by GRIGG at Thames, New Zealand, on April 17th, and had been observed by TEBBUTT at Windsor, N. S. W., on April 26th. The comet was looked for here on the evenings of May 3d and 4th, but it was so near the horizon at sunset that it could not be seen. A telegram giving elements and ephemeris of the comet was received on May 7th. From these it appears that the comet is moving east and south and is rapidly growing fainter. It is not likely to be visible at all from northern observatories.

It will be seen that nine days elapsed between the time of the comet's discovery and the date of the first accurate observation, and six more days were needed to get the news to northern observatories. These were unfortunate delays, though presumably unavoidable. Had news of the discovery reached us promptly some observations of the comet could have been secured here.
R. G. AITKEN.

May 14, 1903.

REPORTS OF OBSERVATORIES.

THE LAWS OBSERVATORY OF THE UNIVERSITY OF MISSOURI, COLUMBIA, MISSOURI.

The work of the Department of Astronomy of the University of Missouri consists of instruction in the various branches of the science as presented to the students of the University, and in the prosecution of such observations as can be made satisfactorily with the equipment of the Laws Observatory.

The principal instrument of the observatory is a 7½-inch equatorial, constructed by Merz & Sons about 1848. The objective is of fair quality, although the glass entering into it is somewhat defective. The mounting is of the original Fraunhofer design, with the slight modification introduced by Merz, and, though inconvenient, and in some respects defective, the instrument is, nevertheless, serviceable for many kinds of observations. The driving-clock, fitted with a Fraunhofer governor, is of the type found upon all the Munich instruments of that period. Until recently the telescope has been supported by a wooden framework which stood upon a brick pier terminating two feet below the floor of the equatorial-room. The wooden support has been replaced by a cast-iron column, which gives the instrument a thoroughly stable foundation. The lower sections of the column were obtained from Warner & Swasey, and are a part of their standard 8-inch equatorial mounting. The pier-head casting was constructed from designs and patterns made in the shops of the University. The instrument is fitted with a micrometer of the Fraunhofer type and with an excellent modern micrometer by Saegmuller.

The telescope is, in a sense, an historic instrument, as will be seen from the following extract from the University of Missouri Catalogue for 1884-1885:—

> "This telescope was ordered in 1848 from the establishment of Merz & Mahler,* of Munich, for the use of Shelby College, Shelbyville, Kentucky. It was received at Shelbyville in November, 1850, and cost, when mounted, $4,000. It was mounted under the direction of Prof. JOSEPH WINLOCK, and used by him while he was a professor in that institution. After Prof. WINLOCK went to Cam-

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* The telescope bears the inscription: Merz u. Söhne in München.

bridge, Mass., he borrowed this telescope, and, in connection with Dr. B. A. Gould, established there the Cloverdon Observatory. In Loomis's *Recent Progress of Astronomy*, the following statement is made respecting this instrument, which was then the fourth in magnitude in the United States:—

"'The great telescope belonging to Shelby College was loaned to Prof. Joseph Winlock, and was removed to Cambridge, Massachusetts, where temporary accommodations were provided for it, and this establishment is known by the name of Cloverdon Observatory.' . . . 'Numerous observations on comets, and on some of the newly-discovered planets, have been made with this telescope by Dr. B. A. Gould and Prof. Joseph Winlock, some of which have been published in *Gould's Astronomical Journal*. This great telescope has recently been returned to Shelby College.'

"In 1869 Prof. Winlock, who was then Director of the Observatory of Harvard College, went with his assistants to Shelbyville, Kentucky, and there used this telescope in observing the total eclipse of the Sun, which occurred on the 7th of August of that year."

During the past year considerable additions to the equipment of the observatory have been made through various purchases. A Pickering stellar photometer by the Alvan Clark & Sons Corporation, and a disk photometer by Brashear have been obtained. The latter is to be used for testing purposes; the former, for systematic observations of variable stars. The Observatory has been re-wired for electrical connections, and a new and simplified switch-board has been introduced. Considerable quantities of minor apparatus, such as sextants, artificial horizons, testing instruments, batteries, etc., have also been acquired.

Since September, 1901, the time has been occupied mostly in a reorganization of the observatory and in the accomplishment of certain administrative details. The library has been increased through gift by about 600 books and pamphlets, and, through purchase, by seventy-seven volumes.

Since September, 1902, 53 observations of comets have been made. Of this number, 32 were of Comet *b* 1902, 5 were of Comet *d* 1902, and 16 of Comet *a* 1903. Thirty of the observations of Comet *b* 1902, together with an orbit based upon intervals of 26 and 28 days, have been published and distributed in Laws Observatory Bulletin No. 1.

F. H. Seares,

Professor of Astronomy and Director of the Laws Observatory.

ALLEGHENY OBSERVATORY.

The present staff of the Observatory is constituted as follows: F. L. O. WADSWORTH, Director; FRANK K. BAILEY, Assistant; ALICE E. DAVIS, Secretary and Assistant. At present Mr. BAILEY'S time is devoted almost exclusively to the maintenance of the time service; Miss DAVIS has been engaged in library and general correspondence work, and has also rendered very efficient service as a computer.

The new observatory building still remains unfinished, and a considerable part of the coming year must elapse before the books and instruments can be transferred to it from our present site.

Very little progress has likewise been made in getting ready the equipment of the new building. The only points of interest in this connection are the following:—

(1) The disks of the 30-inch refractor, which were ordered of Mantois in June, 1899, were received from him on February 19th of the present year. Both disks are beautifully clear and transparent, and, as far as can be determined by preliminary tests, of first-class optical quality. The constants of both the flint and crown glass have been accurately determined and carefully studied by Professor HASTINGS, who has submitted several alternative designs of optical construction. The final type has not, however, been definitely decided upon.

(2) *The Westinghouse Electrical Equipment.*—After careful consideration of the plans of electrical equipment and proposed research work of the electrical laboratories, Mr. WESTINGHOUSE most kindly and generously volunteered to practically double the amount of his original gift, in order to more fully provide for these purposes. As now provided, the generating plant will consist of two 37½-kilowatt dynamos, directly connected each with a 50 H. P. triple cylinder Westinghouse gas-engine. The dynamos will be specially built to give either direct or alternating currents. As D. C. machines they can be connected in multiple to give a current of 600 amperes at 125 volts, or in series to give a current of 300 amperes at 250 volts. As alternators they will furnish a corresponding current at a mean E. M. F. of 90 volts and 1,800 cycles per minute, which can be transformed by step-up transformers to any voltage desired for induction coil and high potential spark

discharge work, or by step-down transformers to furnish a low voltage current of several thousand amperes for electric furnace work. In this experimental work the low rate of alternation, while unsuitable for electric lighting, is in many cases a decided advantage.

In addition to these generators, the plant will also contain a rotary transformer of 5 K. W. capacity, which can be used to give alternating currents of a higher rate of frequency, *i. e.* 7,200 cycles per minute, if desired. This can be driven either directly from one of the main generators or from a storage battery. The final plans contemplate the installation of a storage battery of at least 100-kilowatt hours capacity, so that using both generators and storage battery in multiple, currents of at least 1,000 amperes at 100 volts, or 10,000 amperes at 10 volts, may be obtained for short intervals for experimental work. At present, however, this storage battery is not provided for.

With the generous assistance and active co-operation of two of the members of our Visiting Committee, funds were secured for the erection of the power-house during the latter part of the year. The building, which has been erected by Beunte & Martin, is now nearing completion. It is entirely of concrete, with Berea stone facings similar in general design to the main observatory building. At present only one story has been erected, the roof, which is flat and of heavy concrete construction, being on a level with the ground about the main building. The northern front faces on the proposed park road, and a flight of stone steps of plain but handsome design leads from the lower terrace level, along which the road runs, to the upper terrace level about the main building.

(3) The construction of the new clocks for the Observatory has been intentionally postponed until some experiments now in progress elsewhere have been completed, and until the new building is ready for their reception. There is no place at the present observatory where further experimental work on the various questions connected with the final design of these clocks can be advantageously carried on, and no place where they could be installed even if finished.

(4) The contract for the Keeler Memorial Telescope, both optical parts and mountings, was let to the John A. Brashear Company, January 24, 1902. The disks for the 30-inch specu-

lum and the 18-inch and 12-inch flats for the attached cœlostat and polar heliostat were received on March 26th, and have been roughed out and fined ready for the final polishing and figuring. The two observing floors for the instrument have been erected and the heavy cast-iron piers delivered at the observatory, but have not yet been placed in position. I regret to report that very little work has been done on the mounting itself, but this is now being pushed more rapidly.

(5) The principal optical parts of the Porter 10-inch grating spectroscope have been begun, but no work has been done on the mounting.

(6) The two small domes have been erected and wood-sheathed, but not yet covered with metal. The form of running gear originally designed for these domes was changed by the Observatory Committee after the contract for the steel work was let. This change in the former involved other changes in the latter, which have somewhat delayed the construction and erection of the domes, and which have prevented the carrying out of certain special features of the control and operation of the smaller dome that from the standpoint of the astronomer seemed most desirable. This is to be regretted, as experience has conclusively shown that convenience and ease of operation of the instrument and its accessories is a prime requisite to efficiency in modern observational work of a spectroscopic and astrophotographic character.

No changes have been made in the present observatory building or its equipment during the past year. As has already been stated, it is unsuited for any experimental or observational work. Even the rooms used for offices and library are becoming unsuitable for further occupancy.

GENERAL NOTES.

WILLIAM HARKNESS.— For the following account of the late Professor HARKNESS we are indebted to one of his life-long friends and colleagues:—

WILLIAM, son of JAMES and JANE (WEILD) HARKNESS, was born at Ecclefechan, Scotland, December 17, 1837. His parents were natives of Scotland, and came to New York in May, 1839. The father was a Presbyterian clergyman and also a physician of the homeopathic school.

During his boyhood WILLIAM lived in New York City and in Fishkill, N. Y., and attended the Chelsea Collegiate Institute in New York, and private schools in Fishkill Landing and Newburgh, N. Y. He entered Lafayette College in 1854, but, owing to the removal of his parents to Rochester, N. Y., he became a student in Rochester University in 1856, graduating there with the degree of A. B. in 1858. From Rochester he received the degree of A. M. in 1861, and that of LL.D. in 1874. From Lafayette he received the honorary degree of A. M. in 1865. He was a reporter in the New York Legislature in 1858 for the *Albany Atlas and Argus;* and in the Pennsylvania Senate, in 1860, for the *Harrisburg Daily Telegraph.* The skill acquired in this work as a stenographer was of great service to him throughout his active life. He studied medicine and graduated from the New York Homeopathic Medical College, receiving the degree of M. D. in 1862.

On August 1, 1862, he was appointed an "aid" at the United States Naval Observatory. After the second battle of Bull Run, August 30, 1862, he volunteered as a medical man to assist in the relief of the wounded.

On August 24, 1863, he was appointed a Professor of Mathematics in the United States Navy, with the relative rank of Lieutenant-Commander, to fill a vacancy caused by the death of Prof. JOSEPH HUBBARD. During EARLY's attack on Washington, July 11-12, 1864, he served as a volunteer surgeon.

From October 17, 1865, to June 28, 1866, he was attached to the United States monitor *Monadnock* for the purpose of observing the behavior of her compasses under the influence of the heavy iron armor of the vessel. During this period the *Monadnock* made the trip from Philadelphia around Cape Horn to San Francisco, and Professor HARKNESS made observations to determine the terrestrial magnetic declination, inclination, and horizontal force at the principal posts on the route. The observations and the discussion of the results were published by the Smithsonian Institution in 1871, a quarto volume of 225 pages, under the title, "Observations on Terrestrial Magnetism and on the Deviation of the Compasses of the United States iron-clad *Monadnock* during her cruise from Philadelphia to San Francisco in 1865 and 1866, by WILLIAM HARKNESS, M. D."

On returning to Washington he was attached to the Hydrographic Office from October 14, 1866, to October 1, 1867, and to the Naval Observatory from October 1, 1867, to May 30, 1874.

On August 7, 1869, he observed the total solar eclipse at Des Moines, Iowa, and at that time discovered the now well-known Coronal line K 1474.

On December 22, 1870, he observed the total solar eclipse at Syracuse, Sicily, and early in 1871 visited several of the principal observatories in Europe.

On November 13, 1871, he was appointed one of the original members of the Transit of *Venus* Commission, and was principally employed with other members of the Commission in arranging for the observations of the transits of December 9, 1874, and of December 6, 1882. From November, 1871, to the time of his detachment from the Observatory in 1874, he did but little observing but devoted most of his time to work of the Transit of *Venus* Commission. Professor HARKNESS was formally detached from the Observatory on May 29, 1874, and did not resume his connection with astronomical work at the Observatory for twenty years.

He was in charge of the Transit of *Venus* party at Hobart, Tasmania, where the weather on December 9, 1874, was favorable for good observations. On June 22, 1875, he was ordered to the Observatory for service with the Transit of *Venus* Commission in connection with the reduction of the observations by the different observing parties.

For the purpose of utilizing the photographs taken by these parties Professor HARKNESS devised a measuring engine for determining with sufficient accuracy the relative positions, on the plate, of the centers of the Sun and *Venus*. About this time he designed an attachment to a spherometer caliper for measuring the figure of pivots of astronomical instruments.

He observed the Transit of *Mercury* on May 6, 1878, at Austin, Texas; and the total solar eclipse of July 29, 1878, at Creston, Wyoming. He also edited the volume containing the reports of the observations of the 1878 eclipse. In 1880 and 1881 the photographic observations of the Transit of *Mercury* were reduced under his supervision.

About this time he was engaged with others in making experiments to determine the best form of apparatus for photographing the solar corona during total eclipses.

In 1881-83 he did some work on the reduction of GILLISS's Zones, observed at Santiago, Chile, in 1849-52.

For some time previous to 1882 he was employed, under the direction of the Transit of *Venus* Commission, in making preparations for observing the transit of *Venus* on December 6th of that year. He observed the transit of *Venus* from the grounds of the Naval Observatory in Washington and was afterwards assigned to the duty of reducing all the observations made by the parties organized under the Transit of *Venus* Commission. In about six years the result from the photographic observations was reached and a brief statement was published in a report to the Secretary of the Navy.

From 1888 to 1891 he was principally occupied with his work on "The Solar Parallax and its Related Constants," which was printed in 1891. From 1891 to 1894 he was engaged in miscellaneous work, some of it relating to the building of the new Naval Observatory and the construction of some of the new instruments.

On October 21, 1892, he was appointed chief astronomical assistant to the Superintendent of the Naval Observatory and on September 21, 1894, he was appointed Astronomical Director of the Observatory with general supervision of all the astronomical work. On June 30, 1897, he was appointed Director of the American Ephemeries and Nautical Almanac, and he retained both these offices until his retirement for age, December 17, 1899, with the rank of Rear-Admiral.

Professor HARKNESS published many scientific papers and was a member of a number of scientific societies.

He was a founder and at one time President of the Cosmos Club in Washington, a President of the Philosophical Society of Washington, Vice-President of the American Association for the Advancement of Science in 1881 and 1885, and President of the same society in 1893.

His principal public addresses were:—

Vice-Presidential address before Section A, American Association for the Advancement of Science, on "Transits of *Venus*";

Presidential address in 1887 before the Philosophical Society of Washington, on "The Progress of Science as Exemplified in the Art of Weighing and Measuring";

Presidential address in 1894 before the American Association for the Advancement of Science, on "The Magnitude of the Solar System."

During Professor HARKNESS'S service at the Naval Observatory, from 1862 to 1874, he worked as an observer with the Prime Vertical Transit, the Mural Circle and the Transit Circle. He had charge of the latter instrument from January 1, 1870, to May 29, 1874. As an observer, he was methodical, painstaking, and especially careful in regard to the most minute details. A duly formulated regulation always received his profound respect.

Soon after 1871 his health seemed to demand special care, and from that time until his detachment in 1894 he did very little observing.

His principal work from 1874 to 1894 was with the Transit of *Venus* Commission and after the transit of 1882 he had charge of all the reductions. The general government spent large sums of money in fitting out the various observing parties in 1874 and 1882 and many thousands of dollars in measuring the photographic plates and in making the necessary reductions. Much interest was felt among astronomers in regard to the deduced value of the solar parallax and the Commission authorized and urged a speedy reduction of the work. In 1889 a brief report, announcing the value of the solar parallax as found from the measures of the photographic plates, was printed but no further progress has been made. The value of the parallax from the telescopic observations of the four contacts has not been computed nor have the reports of the observers been printed.

For many years much dissatisfaction had existed among the astronomers of the country with the management of the Naval Observatory, the only government institution of its kind. Many efforts had been made to secure a competent astronomer for superintendent but without success.

Soon after the observatory was moved to Georgetown Heights the pressure from astronomers outside of Washington became so great that it was deemed politic to make an apparent concession to the demand, and the position of Astronomical Director was created by order of the Secretary of the Navy. By the terms of that order the entire astronomical work of the observatory was placed under the supervision of the Director, but he had no adequate control of the personnel. In reality the order bestowed the maximum of responsibility and the minimum of power.

The selection of the proper person for Director was not an easy task. To many of the available officers it was a very undesirable berth. Finally it was accepted by Professor HARKNESS, against the advice of friends, and he assumed the duties with the firm belief that the complete success of the new departure was assured.

To that end he labored with great zeal, devoting his whole time and strength to the cause.

The magnitude of the undertaking and its probable failure were soon apparent, but to the day of his retirement he worked and hoped for ultimate success.

After he left the Observatory the office was continued but a little more than a year.

The work of Astronomical Director and as Director of the Nautical Almanac had already begun to affect seriously his constitution and when, in January, 1900, he attempted to take up again some portions of the unfinished Transit of *Venus* work he was unable to recognize the meaning of the formulæ with which he had been so familiar but five years before. Attributing this failure to nervous prostration he went to his home in Jersey City where he hoped that a few weeks of rest would completely restore his health. There his condition changed but little until February, 1903.

Occasionally some slight improvement would occur but it would be of short duration, and he was unable to do any mental work beyond writing a short letter.

On February 18th it was manifest that Bright's disease had developed. Its progress was rapid; and, happily forgetting his worries and struggles, he passed on peacefully on the afternoon of February 28, 1903.

Spiral Nebulæ.—Sir ROBERT BALL in his lectures on "Astronomical Problems," in London recently, drew attention to the spiral form of many of the great nebulæ. Professor KEELER, he remarked, had during his lifetime attempted to make a chart of the sky by means of photographs taken with the great Crossley reflector at the Lick Observatory. For this purpose he divided the sky into sections, and had intended to photograph each in turn. This task he did not accomplish; but whereas before his investigation began the number of known nebulæ was about 8,000, his investigation left this number multiplied to at least 120,000. Now, there were nebulæ and nebulæ; they differed as one star differs from another in glory; their variety was infinite. They might be divided into young nebulæ and adult nebulæ. Professor KEELER found that half the nebulæ of the sky were spiral nebulæ, and presented us with the astonishing fact that next to a fixed star the spiral nebula was the most characteristic object of the sky. The spiral nebula was to be regarded as an adult nebula, because Sir WILLIAM HUGGINS's beautiful spectroscopic method revealed to us that its spectrum was a continuous spectrum, and that therefore the nebula was no longer a mere chaos of incandescent gas, but had begun to condense down into something more approaching substance. The evolution of the chaos of gas into a spiral proceeded solely from the mutual action of its parts.

ANDREW GREIG.

Source of the Sun's Heat.—In another lecture Sir ROBERT BALL considered the sources of the heat of the Sun. He reviewed the theory of HELMHOLTZ. According to this theory, the Sun is shrinking. It shrinks sixteen inches in diameter daily; it has been shrinking daily ever since it was a great gaseous nebula, extending over a millionfold greater extent of space. Now, the molecules of a body—we may, for clearness, think of a gaseous body and of the molecules of a gas—are in constant vibration while the body is radiating heat. If heat is added to the body, the rapidity of the motion of the molecules increases. Conversely, if the rapidity of the movement of the molecules increases, more heat is given out. The falling in of the Sun's circumference due to the sixteen inches of daily shrinking gives these molecules some distance to fall. It is not a great distance, but there are a great many molecules. Their motion is increased by their daily drop of sixteen inches. Consequently, this addition to their velocity adds to their heat, and thus by the Sun's shrinking the supply of radiated heat is lifted towards the level of the expenditure. But the lecturer proceeded to show that this is not a complete or a completely satisfactory explanation. We may take it that in shrinking from its nebulous form down to its present dimensions the Sun has given out heat equivalent to about 3,400 times its own mass in coal. Each coal unit would have lasted the Sun 2,800 years. If we continue this calculation, and seek to find the number of coal units that the Sun will have consumed between the time it was a gaseous nebula and the time when it shall become a solid body as dense as the densest substance known,—platinum,—we find that it will have consumed 8,300 coal units. In other words, roughly speaking, 24,000,000 years will have elapsed. But 24,000,000 years between the Sun's gaseous nebulous state and the state in which it will become at least as cold as the Earth is now, and cease practically to give out heat at all, is not enough. We know by various considerations that this estimate is too small, and therefore there must be other possible sources of the Sun's heat. What other sources were there? The fall of meteors into the Sun had been suggested: but it was shown by a simple calculation that the quantity of meteors, traveling at 400 miles a second, which would have to fall into the Sun each day to keep up its heat would have to be equivalent in mass to the Moon.

Finally, Professor BALL considered another point. The Earth received heat from the Sun, but the Sun was radiating heat everywhere. If a spectator on the Sun compared the space in the heavens occupied by the Earth with that occupied by the Great Nebula in *Orion,* he would find that the Earth occupied only one two-hundred-thousandth part as much space as the *Orion* nebula. Therefore, we had this fact, that the Great Nebula in *Orion,* though it was a million times farther from the Sun than we were, was receiving 200,000 times as much heat a day. Now, there were visible to our telescopes perhaps about 120,000 nebulæ—all giving out heat, as the Sun had been for ages giving out heat, and all of them sending out heat in all directions. If the nebulæ of the sky had all received heat from the Sun, then—and here was the point—the solar nebula had received heat from the stars in its turn.

ANDREW GREIG.

The Age of the Sun.—Sir ROBERT BALL in his concluding lecture at the Royal Institution, London, dealt with the problem of the age of the Sun, if it were assumed that the Sun and its planets had been evolved from a nebula. He showed the mathematical reasoning by which it is proved that no ray of the Sun can ever escape to infinity. If we supposed the universe to be split up into cubes with sides a billion miles long, a billion miles being the distance of the nearest fixed star, and if at the corner of each of these cubes were placed something no larger than a molecule, no larger even than an "electron," then all the rays of the Sun would be stopped within a finite distance. It would require the universe to be peopled with matter no more thickly than an electron to a billion cubic miles to capture every ray. Now, let the Great Nebula in *Orion* be considered. That nebula caught and stopped one ten-thousandth part of the rays of the Sun; and if the stars above the tenth magnitude be reckoned at 600,000, then *Orion* might be regarded as stopping the whole light of sixty stars during the whole of its life as a nebula. The energy thus received would immensely add to its own energy. Similarly, the rays of energy which the Sun, once a nebula perhaps not much less in size than the great Dumbbell Nebula, had received must have greatly prolonged its life as a nebula. The 24,000,000 years which were all that could be allowed it, had it received no energy from outside, must have been increased to a higher order of number altogether. Professor BALL did not hesitate to write the figure as a hundred million years, and that, he hinted, he regarded as much too small for the age of the Sun. ANDREW GREIG.

The South Polar Cap of Mars.—In the May number of the *Astrophysical Journal,* Professor E. E. BARNARD gives some account of his observations of the South Polar Cap of *Mars,* made at the Lick Observatory during the oppositions of 1892 and 1894. In addition to the usual drawings of the planet, Professor BARNARD made careful micrometer measures of the diameter of the Polar Cap throughout both oppositions,—a practice that is heartily to be commended in the study of all planetary markings. Recently Professor BARNARD reduced these measures to the mean distance of *Mars,* and then drew curves, using the measured diameters of the Polar Cap as ordinates, and the days before or after the summer solstice for the southern hemisphere of *Mars* as abscissas. Two facts of great interest are at once evident from these two curves: (1) they are parallel throughout, showing that the cap at both oppositions followed with surprising closeness the same law of decrease; and (2) the cap continues to decrease for a month or more after the summer solstice, indicating that on *Mars,* as on the Earth, the time of highest temperature is not reached until several months after the maximum of solar heat.

Professor BARNARD seems to incline to the early view that the Polar Caps on *Mars* are due to accumulations of snow, saying that this is as good a theory as any of those put forward to-day to explain the phenomenon.

At the last annual general meeting of the Royal Astronomical Society the society's gold medal was awarded to Professor HERMANN STRUVE, Director of the Königsberg Observatory, for his work on the satellites of *Saturn.*

Dr. FRANK SCHLESINGER resigned his position as observer in charge of the International Latitude Station at Ukiah, Cal., on May 1st, 1903, to accept a position at the Yerkes Observatory. Dr. S. D. TOWNLEY is Dr. SCHLESINGER's successor at Ukiah.

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Mr. S. D. Townley	*First Vice-President*
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OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Felipe Valle.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

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SUGGESTIONS CONCERNING FUTURE OBSERVATIONS OF THE SATELLITES OF *URANUS*.

By PROFESSOR HERMANN STRUVE.

The Tables of the Satellites of *Uranus*, published by Professor NEWCOMB in the "Washington Observations, 1873," can, by small changes of the mean motions, be brought in tolerable agreement with modern observations. Therefore, if we content ourselves with an approximate representation of the motions of the satellites, and if we make abstraction of the changes produced by the inclinations of the orbits, by their eccentricities, the secular motions and the reciprocal perturbations of the satellites, the tables mentioned will probably be sufficient for a long time. Future observations will then only contribute to a more exact knowledge of the mean motions of the satellites and of the mass of the planet. However, particular interest is connected with the small changes mentioned, especially as we may get thereby an answer to different questions concerning our knowledge of the planet, and as we may arrive at further conclusions by comparison with other systems of satellites.

By reason of the extreme faintness of the satellites, particularly of the two inner ones, such observations can only be made with some hope of success by the most powerful instruments. Also, the southern position of the planet during the next two decades forces us to exclude the participation of the more northern observatories. But on account of the numerous great refractors which at present are at the disposition of American observatories it may be expected that the observations necessary for the researches mentioned may be procured in the near future. With this view I beg leave to submit the following suggestions.

The observations made until now have proved that the satellites of *Uranus* move approximately in one and the same plane, not changing during a considerable space of time. Supposing, then, that in analogy with other planets *Uranus* has a sensible ellipticity, and neglecting the small masses of the satellites and the inconsiderable, in this system hardly perceptible, action of the Sun, it is evident that the orbits of the satellites form only small angles with the equator of the planet. For the secular motions of the satellites only some maximum values may be fixed at present, as the ellipticity of the planet is not yet determined by accurate observations. Assuming the greatest possible value of the ellipticity $\frac{a-b}{a} = 0.1$ and the major semi-axis of the planet $a = 1''.9$, the homogeneity of the planet would lead to the following values of the yearly motion of the apsides and of the nodes:—

	$\Delta\pi = -\Delta\Theta$
Ariel,	55°. 2
Umbriel,	17 . 7
Titania,	3 .14
Oberon,	1 .13

Then, again, supposing the relations similar to those of *Jupiter* and *Saturn*, the values mentioned ought to be diminished to their half. It is to be remarked that, accepting $\frac{a-b}{a} = \frac{1}{14}$ and the time of revolution of the planet in round numbers equal to ten hours, as with *Jupiter* and *Saturn*, we shall find nearly the same value for the well-known constant of ellipticity: $\frac{\kappa}{a^2} = \chi - \phi \; 2$ as with those two great planets. Of course these numbers represent only an approximate estimate of the amount of the secular motion produced by the ellipticity. The motions produced by the satellites are even less sensible, if their masses are of the same order as those of the interior satellites of *Saturn*. Considering now that the observations of the satellites *Oberon* and *Titania* present only very small deviations from circular orbits, it is evident that only by observations of the two interior satellites, *Ariel* and *Umbriel,* the eccentricities and inclinations of which may be equal to 0.02 and 1° or 2°, respectively, can a solution of the problem to determine the motions mentioned be expected in a comparatively short time.

For the observation of those two satellites it may be particularly recommended to join both with *Titania,* whose orbit apparently offers the smallest eccentricity, by measures of position-angle and distance. The direct junction of the small satellites with the center of the planet, using bright micrometer-wires, is exposed to the objection that the pointing of the satellites will be different from the pointing of the limb of the planet, on which the wire appears as a dark line. From this circumstance considerable errors depending also on the position-angle might be produced. Also the junction of the interior satellites with *Titania* will no doubt be more exact. Such measures being made during one and the same opposition in sufficient number, and being continued in the same way through several oppositions, the elements of the planes of *Ariel* and *Umbriel* (γ, θ) with their yearly changes will be found nearly independent of the supposed elements of *Titania.* The elliptic elements (e, π) can not be deduced with the same accuracy and independent of the corresponding elements of *Titania,* but even in this case we may expect to ascertain the deviation from the circular orbit, particularly as the lines of the apsides of *Ariel* and *Umbriel* will probably show considerable motion in a few years.

Similarly, the determination of the elements of the planes (γ, θ) of *Oberon* and *Titania* will be most favorably obtained by the junction of these two satellites with each other. But the deviation from the circular orbit (e, π) being very small for both satellites, will result with only small weight. To determine this it is more profitable to join these satellites directly to the planet. As it appears not quite impossible that by the most powerful instruments we might see *Oberon* and *Titania* in the feebly illuminated field, the joining of the two satellites with the limbs of the planet by rectangular coordinates x, y might be recommended. This method of measures has been executed by me several times for the satellites of *Mars* as well as of *Saturn,* with an accuracy which, some precautions being observed, will not be much inferior to the junction of the satellites with one another.

It appears that in general the elements e, π for the satellites of *Uranus* will be determined at other times than the elements γ, θ. At the present time, and during several years to come, when the orbits are wide open, we have the best opportunity for the determination of e, π, but there is no chance to determine γ, θ with more accuracy than it has already been done for *Oberon* and *Titania*. Not before ten or fifteen years will the elevation of the Earth above the orbits of the satellites diminish so far that we may proceed to a new determination of the planes and of their secular variations.

Of course, for the theory of the system of *Uranus* it would be most important to remove the uncertainty which still exists concerning the ellipticity of the planet. Also, in this regard an answer can be expected, particularly from the large refractors having the advantage of larger focal images than the smaller telescopes. In this connection attention may be called to the suggestion made by Professor SEELIGER (*Sitsungsberichte München,* Band XIV) some twenty years ago: To examine by the help of prismatic eye-pieces in what degree the determination of the diameter may depend upon the direction to the horizon. Further, it appears to me that the atmospheric dispersion may be a source of error not yet sufficiently considered, by producing a different coloration of the borders of the planet which will interfere with the uniform pointing of the micrometer-wires on the planet's limbs. This source of error, which has proved to be very important in my measures of *Saturn*, being partly physiological, can affect in different manner the measures of different observers, and may perhaps explain the considerable differences of the various determinations of the ellipticity. When the elevation of the Earth over the planes of the satellites has diminished so far that the ellipticity may be determined anew,—that is, in about ten or fifteen years,—it will certainly be necessary to attempt the elimination of the source of error mentioned by the use of a prismatic eye-piece and by executing the measures in different hour-angles and directions.

KOENIGSBERG, May, 1903.

THE SPECTRUM OF *O CETI.**

BY JOEL STEBBINS.

On account of the great instrumental power required for the observation of the spectra of faint objects, changes in the spectra of long-period variable stars have not been well studied. In fact, there is no star which undergoes a large variation in brightness whose spectrum has been systematically followed from maximum to minimum, or *vice versa.* It is proposed to give here the results of a study of the spectrum of *o Ceti,* or *Mira,* made, at the suggestion of Director CAMPBELL, with the thirty-six-inch refractor of the Lick Observatory, from June, 1902, to January, 1903. During this period the star faded in brightness from 3.8 to 9.0 magnitude. The first photograph of the spectrum was obtained about three weeks after the predicted time of maximum, and a series of plates was secured, covering the interval to minimum. No negatives were obtained after the star had again begun to increase in brightness.

The most important articles concerning the spectrum of *Mira* are those of VOGEL,† SIDGREAVES,‡ and CAMPBELL.¶ Neither VOGEL nor SIDGREAVES followed the star long enough to find much change in its spectrum, and CAMPBELL'S work was mainly in connection with observations of the star for radial velocity, with the Mills spectrograph.

The spectrograph used in my observations was the one employed by Messrs. CAMPBELL and WRIGHT in their work on *Nova Persei* [L. O. Bulletin No. 8], designated as "Spectrograph I." It is the regular Mills spectrograph converted into a one-prism instrument. It gives good definition, on the same photograph, of the region from λ 3700 to λ 5600. Although this dispersion is only about one fifth of that of the three-prism instrument, it is enough to yield a very fair determination of velocity.

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* Dissertation in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the University of California. (Abstract.)

† H. C. VOGEL. Ueber das Spectrum von *Mira Ceti.* Sitzungsberichte der Berlin Acad., 1896, p. 143.

‡ WALTER SIDGREAVES. The Spectrum of *o Ceti* as Photographed at Stonyhurst College Observatory. *Mon. Not. Roy. Astr. Soc.*, Vol. 58, p. 344, April, 1898.

¶ W. W. CAMPBELL. Note on the Spectrum of *o Ceti. Astrophysical Journal,* Vol. IX, p. 31, January, 1899.

When the seeing is good an exposure of ten minutes will give a satisfactory negative of a star to which the Draper Catalogue assigns the photographic magnitude 5.0. If o Ceti were of about the tenth photographic magnitude at minimum, it would require roughly an exposure one hundred times as long as a fifth-magnitude star, or about sixteen hours. Some of the light being in bright lines, we should expect a still longer exposure to be necessary. This estimate agrees with my experience. About July 1, 1902, an hour's exposure, just before daylight, could be made on the star, and it was bright enough to photograph at that time. An exposure of six hours at the time of minimum, using the fastest photographic plate obtainable, was not sufficient to produce a measurable image, although much could be seen in a qualitative way. On January 5, 1903, the date of my last negative, an exposure of five hours, beginning soon after sunset, was possible. Early in March, 1903, the spectrum was again bright enough to record itself with a fairly short exposure; and, in the absence of the writer, Messrs. Reese and Curtis were ready to make an attempt, but bad weather prevailed.

As is well known, o Ceti and the other long-period variables have absorption spectra of Secchi's third type. Since observ- [illegible]

[illegible] plates and then [illegible]

[illegible] are present in the spectrum of the star, the [illegible] lines being much more intense than in the solar spectrum. The strong [illegible] lines of the Sun are not so prominent in o Ceti; in fact they do not show with low dispersion. Of the large number of lines in the star spectrum, there are few which coincide with lines of like intensity in the solar spectrum.

The absorption spectrum of *Mira* was measured accurately on six plates. Each plate was measured and reduced independently, so that a faint line might be measured on one plate without being noticed on any of the others. This does not mean that it had developed, or that its intensity had changed. Such lines, of which many were measured, could be easily obscured by an irregular arrangement of the silver grains. The best method of verifying changes is to examine different plates simultaneously, in pairs, under the microscope. This has been done, and all changes in intensity or character have been noted.

About one hundred lines were measured in the region from λ 3900 to λ 4400. Residuals have been formed by subtracting the mean wave-length of each line from its measured wave-length on each plate.

The residuals for each plate have been averaged; and if there were any change in the velocity it would appear in the mean residuals. The arithmetical means of the residuals to the violet of λ 4400, and the corresponding velocities in kilometers per second, are as follows:—

Date.	Plate No.	tm.	km.
1902, July 6	7 C	+0.02	+1
16	13 E	+0.06	+4
Aug. 4	25 F	—0.03	—2
11	27 D	—0.02	—1
25	28 D	—0.03	—2
1901, Aug. 17	2235 D	+0.02	+1

When it is remembered that all lines, good and poor, were included in the means, and that these plates were taken with a one-prism instrument giving a dispersion of but one fifth of that of the regular Mills spectrograph, the range of only 6^{km} on six plates is very satisfactory. None of the plates taken later in 1902 are good enough to afford comparable conclusions as to the velocity; and it was thought best to measure only first-class plates in this connection.

The result that the star's velocity was constant over a certain period was derived without assuming the coincidence of any of the star lines with lines of the solar spectrum, or with other known lines. A determination of the actual radial velocity requires an assumption as to what the wave-lengths of the star lines would be if they were not affected by velocity. Agreements of star and solar lines were looked for, by direct comparison of the star plates with a solar plate, and only ten coincidences were found. Six of these lines were good enough to be used for determination of velocity, and they give $+66^{\mathrm{km}}$.

CAMPBELL in 1898 found $+62^{\mathrm{km}}$ with the three-prism instrument. The interval between August 29, 1898, the date of his first plate that year, to August 25, 1902, the date of my last plate which was measured, is equal to 130 days more than four periods of 331 days. The radial velocity has therefore been observed to be constant over about two fifths of the period of light change.

To determine more coincidences, I have measured one of the high-dispersion plates of o *Ceti,* taken by Dr. CAMPBELL in 1897. Although the plate is under-exposed, about seventy lines were measured between λ 4300 and λ 4420, and more than twenty coincidences were found by direct comparison with a solar plate. My measures of this plate give a velocity of $+63^{\mathrm{km}}$.

A brief summary of the number of dark lines of different elements observed in the spectrum with both three- and one-prism instruments, may be of interest:—

Element.	No. of Lines.
Ca	6
Fe	11
Cr	9
V	11
Al	2
Sr	1
Mn	3 } ?
Ti	2 }

There can be no doubt of the presence of the first four elements in the list, and the aluminum and strontium lines are prominent; but manganese and titanium must be considered as doubtful.

On account of the varying instrumental conditions it is easy to fall into error in judging as to changes in the intensity and character of dark lines. If all the negatives were of the same density and of uniform excellence, it would be easy to note such changes. There is one dark line which showed changes of which the reality is certain. This is the *g* calcium line at λ 4227.84. Measures of its width are necessarily rough, and must depend much upon the judgment of the observer. The measures of two plates are as follows:—

Date.	Plate.	Width.
1902, June 27	2 B	2^{tm}
September 6	33 D	9

Other plates taken between these dates gave intermediate values.

The general impression formed from examining the series of plates is, that many other lines also grew broader as the brightness declined, but this is not certain. The effects of greater width of the slit, reduced intensity of the resulting negative, and flexure and temperature changes resulting from longer exposure, would all tend to make the lines wider and less sharply defined. The *H* and *K* lines are not shown on most of the plates, and nothing can be said as to changes in their character.

A few lines not visible on the early plates became prominent later. Lines of the solar spectrum which certainly coincide with these have not been found.

The prominent bands in the spectrum of *Mira* have been considered by some observers as a series of dark bands, with sharp edges toward the violet, and shading off toward the red. Others think them to be bright flutings like those of the arc spectrum of carbon. For convenience, they will be considered, in this paper, as dark absorption bands. On the plates of o *Ceti* and other third-type stars taken with Spectrograph I, the bright portions of the banded spectrum are certainly brighter relative to the region above $H\gamma$, where there are no bands, than are the corresponding portions of the spectrum of a solar-type star. However, the dark portions are fainter than the same places in the solar type of spectrum.

No attempt was made to determine the position of the more diffuse ends of the bands. In many cases the intensity changes gradually from head to head, there being heavy absorption at the sharp edge, the spectrum growing uniformly brighter to the next line of demarcation.

SIDGREAVES, on comparing the spectrum of *o Ceti* with that of *α Herculis* and other third-type stars, found a difference in the wave-length of the same band in different stars. For the head at λ 5447 in *o Ceti,* he found the position of λ 5458 in *α Herculis,* and intermediate values for *α Orionis* and *β Pegasi.* He suspected these discrepancies to be due to instrumental causes, but of this he was not certain. His work being done with an objective prism, he had no comparison spectrum with which to test the reality of the observed differences.

Along with the work on *o Ceti* in 1902, plates were taken of *α Herculis, β Pegasi, ρ Persei, α Ceti,* and *α Orionis.* As these stars are all bright, the exposures on them were comparatively short, from five minutes to one hour. Isochromatic plates were used, so that a range of spectrum as far to the red as λ 5600 was covered. They were measured only for the positions of the heads of the bands. In the spectrum of *Mira* there are few dark lines shown in the region of the bands, but in the others many lines were recorded. Where there are more lines the bands are less prominent, and in the case of *α Ceti* and *α Orionis,* only three bands could be measured, while twenty-one were measured in the spectrum of *o Ceti.*

The measures of the bands give accordant results for the different stars, and in but few cases is there a discrepancy of more than one tenthmeter. My measures of the band near λ 5447 give λ 5446.8 from five stars, no star giving a value differing as much as one tenthmeter from the mean. *o Ceti* gives exactly the same wave-length as the mean of the others.

As far as I know, the identification of the bands of the third-type stars has not been accomplished. If the division at λ 5165.9 be considered as the head of a bright band, it is in close agreement with the head of the third carbon band at λ 5165.3, as measured by KAYSER and RUNGE. The head at λ 4737.1, measured in *α Herculis,* may also correspond to their fourth carbon band, λ 4737.2. These two coincidences are the only ones I have found, and we certainly need more evidence before drawing any conclusions from them.

SIDGREAVES found that the continuous part of some regions of the star's spectrum changed in relative intensity as the star grew fainter. These changes have been verified in the present work.

SIDGREAVES's plates showed that as the star declined in brightness, the intensity of the bright portions of the spectrum between λ 4300 and λ 5000 grew less relatively to that of the region near λ 5500. My plates show a decrease in intensity of the region from λ 4300 to λ 5000 relative to the continuous spectrum from λ 4000 to λ 4300.

These changes in intensity have been described as changes in the continuous spectrum, but they may be simply the fading out of some bright bands.

The most noticeable and interesting features in the spectrum of *o Ceti* are the bright lines. The great brilliancy of some of the hydrogen lines, when the star was near its maximum, has been recorded by several observers. The peculiar fact was noticed, that H_α, $H\beta$, and H_ϵ were apparently missing, while others of the hydrogen series were very bright. Photographs, which showed H_γ and $H\delta$ as intense, gave no trace of $H\beta$ and H_ϵ. SIDGREAVES, in 1898 and 1899, found something which from its position might be the bright $H\beta$, but he did not consider it as certain. It has been seen bright on some plates at Harvard. [Vol. 28, Part I, H. C. O.] Mr. WRIGHT found H_ϵ distinctly bright on a plate which he had taken in August, 1901. $H\beta$ and H_ϵ were recorded as bright lines on all the dense negatives taken with Spectrograph I. They seem to have grown stronger relatively to the other hydrogen lines and also to the continuous spectrum as the star grew faint.

An attempt was made to observe H_α visually, but without success, on the night of September 6, 1902, when the instrument was changed to adapt it for visual work. Corresponding to the bright well-defined H_α of the comparison spectrum there was continuous spectrum, but no bright line in the star. Mr. WRIGHT was present and verified the observation. H_α should be looked for when *Mira* is again at a maximum.

The wave-lengths of the bright lines show no more change than do those of the dark lines. The average residual for each plate has been computed and there is no sign of variable position. A comparison of these average residuals with those of the dark lines is as follows:—

Date.		Plate No.	Dark Lines.	Bright Lines.
1902, July	6	7 C	+0.02	+0.01
	16	13 E	+0.06	+0.04
Aug.	4	25 F	—0.03	—0.03
	11	27 D	—0.02	—0.03
	25	28 D	—0.03	+0.03
1901, Aug.	17	2235 D	+0.02	—0.04

These average residuals are all so small that the agreement in sign for some cases is of little significance.

The wave-lengths of the bright lines and the identification of some of them is given in the following table.

There can be no doubt that the hydrogen series is present. Metallic lines which seem to coincide in five cases are given, but in spite of the accuracy of the measures, we must consider the question of their identity to be still open.

IDENTIFICATION OF BRIGHT LINES.

o Ceti λ.	Tabular λ.	Displacement. tm.	Substance.	Authority for λ.
3751.2–	3750.15	+1.0–	H_κ	AMES.
3771.52	3770.7–	+0.82	H_ι	AMES.
3798 76	3798.0–	+0.76	H_θ	AMES.
3836.20	3835.6–	+0.60	H_η	AMES.
3853.51				
3889.91	3889.15	+0.76	H_ζ	AMES.
3906.36	3905.66	+0.70	Si 12	ROWLAND.
3908.18				
3933.45				
3939.10				
3968.49				
3970.87	3970.18	+0.69	H_ϵ	ROWLAND.
4007.74				
4102.66	4101.89	+0.77	H_δ	WRIGHT.
4202.91	4202.20	+0.71	Fe 8	ROWLAND.
4216.71				
4234.12				
4308.70	4308.08	+0.62	Fe 6	ROWLAND.
4341.33	4340.63	+0.70	H_γ	ROWLAND.
4373.61				
4376.78	4376.11	+0.67	Fe 6	ROWLAND.
4571.82	4571.26	+0.56	Mg 5	ROWLAND.
4862.34	4861.53	+0.81	H_3	ROWLAND.

It should be noticed that a bright line developed on each side of each of the strong dark calcium lines, *g, H,* and *K*. Without looking at the plates, this might seem to be due to a double reversal of the calcium lines. Their appearance is not such, however. Mr. WRIGHT also examined the plates with this in mind, and in his judgment the lines are separate bright lines and the phenomenon is not one of double reversal.

Several attempts were made, in June and July, 1902, to secure photographs of the spectrum of *Mira*, with the regular three-prism instrument. It was impossible, however, to make an exposure long enough to record the continuous spectrum. The only features recorded were H_γ and two other bright lines. H_γ was single on all the plates. It seemed nearly monochromatic, but was a little sharper on the violet than on the red side. It had the same appearance as that found by CAMPBELL in 1898, at about the same interval after the star's maximum. In 1898 he found that H_γ was triple from five to two weeks before maximum. Before observations of *o Ceti* were begun in 1902, it had been intended to make polariscopic tests for Zeeman effects in the bright lines; but they were found single on the first photographs, and no observations for polarization were attempted. These should certainly be made when it is again possible to observe the star at maximum. Measures of the three-prism plates give the following displacements of H_γ in tenthmeters.

Date.		Plate No.	tm.
1902, July	2	2446 F	+0.65
	2	2447 A	+0.68
	21	2470 D	+0.65
Aug.	18	2505 E	+0.61
		Mean	+0.65

It is interesting to compare the measures of plates taken in 1902 with those of 1898. CAMPBELL also observed the bright lines near λ 4308 and λ 4376. They were also measured on the high-dispersion plate of August 18, 1902. In the following scheme, under the heading "Bright Lines," is given the actual observed displacement of each bright line, corrected for the Earth's motion. Under "Dark Lines" is given an assumed displacement which corresponds to that of the absorption-lines in the spectrum.

	CAMPBELL, 1898.		STEBBINS, 1902.		
	Three Prisms.		Three Prisms.	One Prism	
Line.	Bright Lines: tm.	Dark Lines, +62km. tm.	Bright Lines. tm.	tm.	Dark. Lines, +66km. tm
H_δ 4101.89	+0.64	+0.85	......	+0.77	+0.90
Fe? 4308.08	+0.60	+0.89	+0.61	+0.62	+0.95
H_γ 4340.63	+0.64	+0.90	+0.65	+0.70	+0.96
Fe? 4376.11	+0.61	+0.91	+0.66	+0.67	+0.96

The dark lines in this region of the spectrum are apparently displaced about 0.25 tenthmeter farther to the red than are the bright lines. The results obtained with one prism are systematically larger than those obtained with three prisms. This may be partly due, in the case of H_γ and H_δ, to over-exposure on many of the plates. Since the lines seem to shade off toward the red, greater exposure probably slightly increases the apparent wave-lengths. However, since the displacements of the other hydrogen lines, which were not over-exposed, are about the same as those of H_γ and H_δ, this effect is probably not large. The difference between the results of 1898 and 1902 is due, no doubt, to personal errors.

The bright lines at λλ 4308 and 4376, marked as possibly due to iron, are of peculiar interest. The appearance of each, on some of the plates, is of a bright line with an adjacent dark one on the red side. If the bright lines be due to iron, they are displaced by the same amount as the bright hydrogen lines; and if iron produces the absorption components, the displacements are equal to those of other dark lines.

A glance at the series of plates showed that there were many changes of intensity among the bright lines, both relative to each other and to the continuous spectrum. The lines at λλ 4202, 4308, and 4571 all became brighter than the hydrogen lines. Of these three, only λ 4202 was visible on the early plates. λ 4571 did not exist at first, but appeared when the star was of about magnitude 5.4, and as *Mira* grew faint this line became the most prominent object in the spectrum.

H_γ and H_δ could not be seen on plates taken near minimum, although they were easily observed a month before. On account of underexposure it can not be said whether the other bright hydrogen lines disappear or not.

Until this star has been successfully followed through all its phases, it is obviously too soon to advance any theory to account for the observed changes in its spectrum or in its brightness. The light-gathering power of the great refractor is not sufficient to follow the spectrum satisfactorily, at least not on the dispersive scale used by me. An ideal equipment for work on variables would consist of a large reflector which could be used for this purpose alone, with spectrographs of various dispersive powers arranged for use in all parts of the spectrum.

The apparent constancy of radial velocity is strong evidence that the variations in brightness are not due to the influence of a companion star, unless, indeed, the companion were of very small relative mass, were moving in a very eccentric orbit, and approached very close to the primary. The displaced system of bright lines could not belong to such a companion, as their wave-lengths are apparently constant. The large irregularities in the period of the light-curve practically preclude the question of a binary system, though perhaps not absolutely so.

The remarkable distribution of light in the hydrogen series seems as yet impossible to explain. Miss CLERKE has explained the apparent absence of H_ϵ by assuming the hydrogen to be at a lower level in the star's envelope than the calcium layer, the *H* calcium absorption destroying the H_ϵ radiations. This theory may still be true, though the existence of a faint bright H_ϵ has been proven. However, $H\beta$ and H_α are much more reduced in intensity than is H_ϵ; and with them there is no evidence of overlying absorption strata. It is usually expected that the bright hydrogen series will diminish in intensity from red toward the violet. This appears to hold even for new stars, in which the disturbance has been very sudden, though exception should perhaps be made for H_α when new star spectra approach the nebular form. The supposition that in *Mira* the hydrogen series may regularly decrease in brightness from violet to red is not tenable, as the diminution from H_γ to $H\beta$ is entirely too great. Inasmuch as the bright lines are strongly shifted (to the violet with reference to the dark-line system) from their normal positions apparently by causes other than radial velocity and pressure, it seems probable that the peculiarities of the hydrogen-line intensities are due also to causes now unknown to us. The presence of the bright iron lines λ 4202, λ 4308, and λ 4376, the absence of others of the same element, and the diversity of structure observed by CAMPBELL in the triple H_γ and H_δ bands are perhaps due to similar unknown causes.

The great variations of relative intensity observed in the hydrogen and other bright lines, and in the continuous spectrum, show that the star's decrease in light is produced by other causes than general absorption.

Considering all the evidence, it seems reasonably certain that the star's variation in brightness is due to the action of internal forces.

I beg to acknowledge my indebtedness to Director CAMPBELL, who provided the necessary apparatus and made valuable suggestions during the course of the work; to Messrs. WRIGHT and REESE, for continual advice and assistance; and to Dr. H. D. CURTIS, for enlarging the negatives for reproduction.

May 1, 1903.

NOTES ON VARIABLE STARS.

By ROSE O'HALLORAN.

Y Cassiopeæ.

The variation of this star, which was discovered on the photographic plates of Harvard College Observatory a few years ago, ranges from 9.8 to 13th magnitude.

According to the comparison-stars of 10.2 and 12th magnitude close above, it was of 11.3 magnitude on the 1st and 2d of August, in 1902, and on October 26th and 31st, and November 3d it had increased to 11th magnitude.

W Aurigæ.

Having become invisible in last December, the predicted maximum was looked for towards the middle of January of this year.

On the 14th, 17th, and 27th, and on February 1st it was still invisible, though a comparison-star of 12th magnitude was seen. The period of *W. Aurigæ* seems to be irregular.

S S Cygni.

This fitful variable was nearly equal to *b* of 8.5 magnitude recently, but has since declined.

1903. June 23, 8:50 P. M.—Two tenths less than *b*. June 24, 25, 26—Decreased, but still brighter than *a* of 9.5 magnitude. June 27, 29—Equal to *a*. June 30, 9:17 P. M.—Slightly less than *a*, but distinctly brighter than *d* of 10.5 magnitude. July 1—Between *a* and *d*, but nearer to *d*. July 2—Dimmer in haze and moonlight; *d* not seen. July 3—Barely discerned in haze and moonlight. July 4, 5—Equal to *d* in hazy moonlight. July 6—Less than *d*, clear moonlight.

W Lyræ.

The recent increase and decline of this star was observed as follows:—

1903. February 21—8.8 magnitude; not equal to *a;* equal to *c*. February 28—8.6 magnitude; brighter than *c*, equal to *a*, less than *n*. Morning clear. March 6, 9, 18, 22—Still equal to *a*. Mornings rather clear. March 25—8.7 magnitude; slightly decreased. April 3—8.8 magnitude. April 11—9th magnitude, according to the comparison-stars. April 22—9.8 magnitude. May 1—10.5 magnitude. May 12—11th magnitude. June 1st—About 12th magnitude; barely visible. June 17, 22, 25, 29—Not visible. July 1, 2, 3—Not visible. July 6—In clear moonlight not visible with a high power.

Classified comparison-stars not being available for the following variables, namely, *W Cassiopeæ, V Coronæ*, and *V Hydræ*, the estimates are founded only on experienced observations. Except in the case of *V Hydræ*, the comparison-stars used were closely adjacent to the variables.

W Cassiopeæ.

1902. August 22—11.5 magnitude. September 25, 27—Invisible. October 26, 28, 31—Invisible. November 3—Invisible.

1903. June 24, 26, 29, 30—Of 10th magnitude. July 1, 2, 3—Of 10th magnitude.

V Coronæ.

1903. April 22—Somewhat less bright than 9th magnitude. May 1—Distinctly brighter, compared to the stars closely adjacent. It was of about 8.5 magnitude.

V Hydræ.

1903. February 4—Less than B^2 of 6th magnitude, but visible in an opera-glass, and probably of 6.7 magnitude. February 12—6.7 magnitude. Moonlight. This is the date of expected maximum. February 19, 23, 25, 26—6.7 magnitude. March 3, 6, 16—6.7 magnitude. April 1—Slightly decreased in telescope and still more decreased in opera-glass. April 11, 16—Ditto. April 26—Of about 7th magnitude, but still visible in opera-glass.

San Francisco, July 7, 1903.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1903.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon,	Sept.	6,	$4^h 20^m$ P.M.	Full Moon,	Oct.	6,	$7^h 24^m$ A.M.
Last Quarter,	"	14,	5 14 A.M.	Last Quarter,	"	13,	11 56 A.M.
New Moon,	"	20,	8 31 P.M.	New Moon,	"	20,	7 30 A.M.
First Quarter,	"	28,	5 8 A.M.	First Quarter,	"	28,	12 32 A.M.

The Sun reaches the equinox and autumn begins September 23d, 10 P. M., Pacific time.

There will be a total eclipse of the Sun on September 20th, but it will not be available for astronomical observations, as the path of totality lies in the most inaccessible region of the globe. It begins in the Indian Ocean, southeast of Africa, and runs eastward and then southward, ending near the South Pole. There is very little land from which even the partial phase of the eclipse can be seen; Madagascar and the southern portions of Australia and New Zealand are about all.

There will also be a partial eclipse of the Moon on October 6th, rather uninteresting to people in the United States, since no part of it will be visible here. It will be visible throughout most of the eastern hemisphere and will be not quite total.

Mercury begins the month as an evening star, coming to greatest east elongation on September 7th. It is then 27° from the Sun, but it is also 10° south; so it remains above the horizon scarcely an hour after sunset, and will not be easily seen. It soon begins to approach the Sun quite rapidly, and passes inferior conjunction on October 3d, becoming a morning star. On October 18th it reaches its greatest west elongation, 18°. This is much smaller than the last; but now the planet is in a part of the zodiac north of that part where the Sun is, and consequently there is a much wider interval between the times of rising of the two bodies. During the latter half of the month *Mercury* will rise from an hour and a half to an hour before sunrise, and this will be the best time of the year for seeing the planet as a morning star.

Venus is an evening star at the beginning of September, too close to the Sun to be seen. It reaches inferior conjunction on September 17th, and becomes a morning star. Its motion is now northward and westward from the Sun, and in a very few days it can be seen in the morning twilight. On October 1st it rises an hour and a half before sunrise, and by November 1st more than three hours and a half. During October it will also be very bright, reaching the maximum on October 24th, and it may be seen in full daylight during the greater part of the month. At the time of inferior conjunction *Venus* is nearly 6° south of the Sun, being in the part of its orbit farthest from the ecliptic. Although the inclination of the orbit of *Venus* to the ecliptic is less than half that of *Mercury* (the greatest in the solar system except the asteroids), yet on account of its nearness to us at inferior conjunction it can attain a greater apparent distance from the ecliptic than any other planet. It is frequently stated in text-books that this distinction belongs to *Mercury*, but it is *Venus* which reaches the greatest latitudes.

Mars is still an evening star, but the Sun is gradually overtaking it in their common eastward motion. On September 1st it sets shortly after 9 P. M., on October 1st an hour earlier, and on November 1st before 8 P. M., less than three hours after sunset. Its total motion during September and October is about 45° eastward and 7° southward, from *Libra* through *Scorpio* into *Sagittarius*. On September 25th it passes about 2° south of *β Scorpii*, and on October 3d about 4° north of *Antares*, *α Scorpii*. Its distance from the Earth in millions of miles increases from 139 to 167, and in consequence of this its brightness will diminish nearly 50 per cent, but there will be no difficulty in identifying it.

Jupiter comes to opposition with the Sun on September 11th, and is then above the horizon the entire night. Toward the end of October it will set an hour or more before sunrise. It is in the constellation *Pisces*, and during the two months moves about 6° westward and 2° southward.

Saturn is also in good position for evening view. It sets at about 2:30 A. M. on September 1st, at about 12:30 on October 1st, and at about 10:30 P. M. on November 1st. It is in the constellation *Capricorn*, and moves slowly westward until October 7th, and then moves eastward, but the whole range of motion is about 1° only.

Uranus is nearer the horizon than *Saturn*, setting shortly after 11 P. M. on September 1st, and at about 7:30 on November 1st. It is moving slowly eastward in *Ophiuchus* between *Scorpio* and *Sagittarius*. *Mars* passes it on October 24th, the brighter planet being about two diameters of the Moon farther south.

Neptune rises shortly after midnight on September 1st and at about 8:30 P. M. on November 1st. It is in the western part of *Gemini*, and moves slowly eastward until October 9th, and then begins to move westward.

(FORTY-FIFTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to JOHN GRIGG, Esq., of the Observatory, Thames, New Zealand, for his discovery of an unexpected comet on April 16, 1903.

The Committee on the Comet-Medal:

W. W. CAMPBELL.
WM. PIERSON.
CHAS. BURCKHALTER.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

COMET *c* 1903 (BORRELLY).

A telegram announcing the discovery of a new comet by M. BORRELLY, at Marseilles, on June 21, 1903, was received here on the evening of June 22d. Observations of it were secured by the writer the same night and the two following nights, and the resulting positions telegraphed to other observatories. The comet at the date of the first observation was in the position R. A. $21^h\ 52^m$; Decl. $-7°$, and was moving slowly westward and more rapidly northward. It appeared to be fully as bright as an eighth-magnitude star, and had a small disk-like nucleus estimated of about the tenth magnitude. A brushy tail could be traced for half a degree in the south preceding quadrant.

The comet's apparent motion has increased very rapidly, owing to its near approach to the Earth, with a corresponding increase in its brightness. On June 30th it was easily visible to the naked eye, and last night (July 14th) it was as bright as a third-magnitude star. Notes on the comet's orbit, and on the photographic and spectrographic observations secured here will be found on another page.

July 15, 1903.

R. G. AITKEN.

THE PHOTOGRAPHIC SPECTRUM OF COMET *c* 1903 (BORRELLY).

A photograph of the spectrum of this comet was obtained on July 15th, using the small slit-spectrograph attached to the Crossley reflector. An exposure of four hours showed the five bands which were photographed in comets *b* 1893 (RORDAME)† and *b* 1894 (GALE)‡, by CAMPBELL. The relative intensities of these bands are also the same, with one exception, allowing for the differences of dispersion and absorption of the instruments used. The band at λ 420 is quite conspicuous in both of the earlier comets, but is very weak in Comet Borrelly.

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* Lick Astronomical Department of the University of California.

† *Astronomy and Astrophysics*, Vol. XII, p. 652.

‡ *Astronomical Journal*, Vol. XIV, p. 111.

Very little continuous spectrum is shown in the photograph, although it seemed quite strong in the visual portion of the spectrum.

C. D. P.

July 19, 1903.

ELEMENTS OF COMET *c* 1903 (BORRELLY).

The following orbit was computed from observations made on June 22d, 30th, and July 10th, by Dr. AITKEN:—

$$T = 1903,\ \text{August}\ 27^{d}.6056,\ \text{Gr. M. T.}$$

$$\left.\begin{array}{rl} \omega = & 127^{\circ}\ 19'\ 25''.5 \\ \Omega = & 293\ \ 32\ \ 55.0 \\ i = & 84\ \ 59\ \ 45.3 \end{array}\right\} 1903.0$$

$$\log q = 9.518126$$

Residuals (O – C):—

$$\begin{array}{ll} \Delta\lambda' \cos\beta' & -1''.0 \\ \Delta\beta' & +5\ .7 \end{array}$$

The orbit of this comet bears no close resemblance to any previously observed.

An extended ephemeris shows that the comet reaches a north declination of over 68° on July 20th. It then turns south, with diminished geocentric motion, and at the time of perihelion is still 45° north of the Sun on almost the same meridian. It will thus be visible as an early evening object until after its perihelion passage, after which it will become a morning object for a few days. As its southward motion is rapid, it will soon after be lost to northern observers.

Its theoretical brightness reached a maximum on July 17th, when it was fourteen times brighter than at discovery. At perihelion its theoretical brightness is 8. Its observed brightness will, in all probability, be greater than theory indicates.

July 19, 1903. C. D. P.

PRELIMINARY NOTE ON PHOTOGRAPHIC OBSERVATIONS OF COMET *c* 1903 (BORRELLY).

Photographic observations of Comet *c* 1903 (BORRELLY) were begun at the Lick Observatory on the night succeeding that of discovery, and are still in progress. Nine exposures, ranging in length from thirty-eight minutes to four hours, have been made with the Dallmeyer camera of 15^{cm} aperture, 82.6^{cm} equivalent focal length, and 14° × 16° angular field. Three negatives with the same range of exposure have been obtained simultaneously with the Floyd camera of 13^{cm} aperture and 178^{cm} focal length.

Two tails, one of which is nearly straight, the other greatly curved, appear on all but the last plate. The curved tail is short and very bright, while the straighter tail is relatively fainter and longer but develops some very interesting forms.

On a plate of four hours' exposure, on June 23d, the tails are widely separated. The straight tail is narrow at the head, but broadens and extends 1½ degrees. On the plate of June 29th the longer tail has split up into two distinct branches, which emerge separately from the head and diverge slightly as they extend into space. With four hours' exposure on June 30th, the secondary tail appears very bright, with a length of 1½ degrees. The primary extends five degrees from the nucleus. The form is indistinct, but the division of the previous night still persists. One branch remains straight, while the other is broader and longer and follows a sinuous curve. On the following night the straight tail is sharp and single.

The plates of July 12th and 13th still show two tails. The primary tail is straight and narrow, and the secondary tail still greatly curved. On the plate of July 12th, with thirty-eight minutes' exposure, the primary tail is four degrees long; the secondary tail is 1.5 degrees in length. The plate of July 14th, $1^h\ 48^m$ exposure, shows one straight narrow tail 8½ degrees in length, widening out slightly as it extends away from the head.

On all the plates the nucleus is sharp and approximately central with respect to the heavy coma.

During these exposures the Earth has been approaching rapidly to the plane of the comet's orbit. At the same time the apparent angle between the tails has steadily diminished until, on the plate of July 14th, they are coincident. Measures of the position-angles of the tails on two plates are given below. P_a, P_b, and P_r represent respectively the position-angles of the primary tail, secondary tail, and radius vector from the

Sun to the comet. The difference $P_a - P_r$ appears in the last column.

No. of Plate.	Date, 1903.	P. S T. of Mid-exposure.	α	δ	P_a	P_b	P_r	$P_a - P_r$
5	June 30	$13^h 33^m$	$21^h 41^m.5$	$+ 2° 48'$	236°.0	216.8	238.0	—2°.0
7	July 12	8 52	20 34 .2	+39 23	197 .3	188.0	199 6	—2 .3

R. H. CURTISS.
SEBASTIAN ALBRECHT.

HONORS CONFERRED UPON MEMBERS OF THE LICK OBSERVATORY STAFF.

The honorary degree of Doctor of Science was conferred upon Assistant Astronomer R. G. AITKEN in May by the University of the Pacific.

Astronomer W. J. HUSSEY was elected Foreign Associate of the Royal Astronomical Society at their meeting May 8, 1903.

W. W. C.

APPOINTMENTS TO LICK OBSERVATORY STAFF.

Dr. JOSEPH H. MOORE, recently of Johns Hopkins University, has been appointed Assistant in Spectroscopy.

JAMES D. MADDRILL, University of California, Class of 1903, has been appointed Fellow in Astronomy in the Lick Observatory for the current academic year.

W. W. C.

D. O. MILLS EXPEDITION TO CHILE.

Acting Astronomer WRIGHT, in charge of the D. O. Mills expedition to Chile, has selected the summit of the hill San Cristobal as the site for the observing station. This hill lies on the northeast edge of the city of Santiago. The altitude of Santiago is 560 meters, and that of San Cristobal about 850 meters. There is a road to the top. "The summit is a ridge about one fourth of a mile long, with three peaks, not unlike Mt. Hamilton."

W. W. CAMPBELL.

MT. HAMILTON, July 17, 1903.

GENERAL NOTES.

Personal Scale.—Almost every observer has a tendency, in estimating the tenths of intervals on scales or micrometer heads, to slight certain tenths and to favor others. This tendency has been called "personal scale" by PEIRCE, who first called attention to it. Not much has been written on the subject, probably because, although very interesting from a psychological point of view, it can never have much effect on observations. Usually all that personal scale does is to increase, in a slight degree, the probable error of one observation.

The writer examined 2,000 readings that he made on a micrometer attached to the zenith telescope at the International Latitude Station at Ukiah. The following table shows the number of times that each tenth was read off (reduced to percentages of the whole). If he had had no personal scale all these numbers should have been 10.0 per cent. The readings were counted in four independent sets of 500 each, in order that their accordance might show the degree of reliability of the means:—

Tenths.	First 500.	Second 500.	Third 500.	Fourth 500.	Mean.
.0	14.1	15.2	14.3	10.0	13.4
.1	11.2	7.4	11.3	9.5	9.8
.2	8.0	10.2	7.9	9.3	8.9
.3	8.4	5.8	8.5	9.5	8.0
.4	13.5	11.2	11.9	11.2	12.0
.5	12.7	15.0	12.9	15.4	14.0
.6	13.1	11.6	11.3	14.2	12.6
.7	4.8	7.2	7.9	5.5	6.3
.8	5.8	9.0	6.6	7.3	7.2
.9	8.4	7.4	7.4	8.1	7.8

It will be seen that this observer tends to slight the high tenths (0.7, 0.8, and 0.9) and to favor 0.0, 0.5, and the two adjoining 0.5. It may be remarked that the tendency to favor 0.0 and 0.5 is the most usual form of this kind of personality.

Personal scale extends to the estimation of tenths of a second in observing transits by the eye-and-ear method. Dr. S. D. TOWNLEY has published (*Astronomy and Astrophysics,* June, 1892) a series of about one thousand such estimations, with the following result:—

Tenths.	Per cent of whole.
.0	15.5
.1	10.3
.2	11.5
.3	11.1
.4	7.9
.5	10.1
.6	10.2
.7	8.3
.8	6.9
.9	8.2

There is here a tendency to slight the high tenths and to favor the zero. It is a somewhat remarkable feature that all the missing sevens, eights, and nines have been called zeros.

Neither of the above personal scales is very marked. The writer came upon a case some time ago of an experienced observer in whom the tendency was particularly strong and very curious. The following shows the results of two independent counts of micrometer bisections, each count embracing 608 estimations:—

Tenths.	Per cent.	Per cent.	Mean.
.0	16.3	21.6	19.0
.1	19.9	16.2	18.0
.2	19.6	19.9	19.8
.3	1.8	2.3	2.0
.4	6.4	1.7	4.0
.5	0.3	0.5	0.4
.6	3.4	1.8	2.6
.7	2.4	3.4	2.9
.8	11.3	18.1	14.7
.9	18.6	14.5	16.6

The crowding to the ends of this scale is very remarkable. This observer apparently had such an aversion to 0.5 that out of 1,216, when it should have been read 122 times, it appears only five times! We should, then, naturally expect that 0.4 and 0.6 would be read more often than they actually occurred, but instead we find that these, as well as 0.3 and 0.7, have been badly neglected. If we add up the percentages for 0.3, 0.4, 0.5, 0.6, and 0.7, we get 11.9; consequently, almost all these readings should actually have been called 0.5. That an experienced observer could have so marked a personal scale is almost incredible, but perhaps it is no more difficult to believe this than to understand the statement regarding BESSEL'S personal equation. It is said that when he used a clock beating half-seconds his personal equation changed as much as 0.49 seconds compared to what it was with the use of a clock beating seconds. If it were almost anybody but BESSEL we should be inclined to think that a cog had slipped somewhere.

F. S.

ANDREW AINSLIE COMMON, LL.D., F.R.S., died suddenly at Ealing, London, on June 2d last. He was born at Newcastle-on-Tyne in 1841. Though an engineer by profession, his strong bent for astronomy declared itself in early manhood, and became practically the pursuit of his life. His home and his observatory were at Ealing, where he had a fine equatorial telescope at work, and devoted himself especially to celestial photography. The satellites of *Mars* received particular attention, also those of *Saturn,* the nebula in the *Pleiades,* and the great one in *Orion,* with some new stars near that constellation. He also studied the nucleus of the noted comet of 1882,—all researches of a kind in which photography would be of special service. On the practical side, Dr. COMMON wrote on the illumination of micrometers, on silvering large mirrors, on the mounting of large telescopes and reflectors, and, at a later date, on the mounting of a three-foot reflector. He was the maker of some very important reflecting equatorials, including the largest of its kind in existence. Elected a Fellow of the Royal Astronomical Society in 1876, he was its President in 1895-96, and mentioned in a report presented in the following year that the five-foot mirror of his direct Cassegrain telescope had been reground, and that, in addition to other concave mirrors, two of thirty inches diameter had been made. In recognition of his work on Celestial Photography, he received the gold medal of the Royal Astronomical Society. Since 1895 he had devoted his attention to the improvement in the sighting of guns of all kinds, and he recently patented a range-finder, which was taken up by the Admiralty. ANDREW GREIG.

FRIEDRICH DEICHMÜLLER, professor at the University of Bonn, and observer at the observatory, is dead. He had been connected with the observatory for nearly twenty-seven years, his chief work there being upon Part Six (40° to 50°) of the *Astronomische Gesellschaft Catalog.* This work contains 50,000 observations on 18,457 stars. Deichmüller made one third of the observations and superintended all the reductions. Of late years his attention had been given almost exclusively to variable stars and to corrections to the *Durchmusterung.* He died in the prime of life, having been born in 1855.

Andrew Graham, for many years chief assistant at Cambridge Observatory, is retiring at the age of eighty-eight. More than fifty-five years ago, Mr. Graham's name became widely known as the discoverer of *Metis,* the ninth asteroid. His chief contribution to astronomy is his work on Part Nine (25° to 30°) of the *Astronomische Gesellschaft Catalog.* All the observations on the 14,464 stars it contains were made by himself, besides which he performed or supervised all the computations.

Lady Huggins and Miss A. M. Clerke were made honorary members of the Royal Astronomical Society at its last meeting. This is a rare honor, having been accorded on only two previous occasions—to Mrs. Somerville and to Caroline Herschel.

The University of Glasgow has conferred the degree of LL.D. upon Sir Norman Lockyer, Director of the Solar Physics Observatory, London.

The two independent determinations of the difference of longitude between the observatories at Paris and at Greenwich have been completed and are shortly to be published,—the one by M. Loewy and the other by Mr. Christie, the respective directors of these observatories.

The new cable to Hawaii offers an opportunity for the determination of the longitude of this place which the U. S. Coast and Geodetic Survey has already taken advantage of. The work is now completed, Assistants Smith and Morse having each observed both at Honolulu and San Francisco.

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

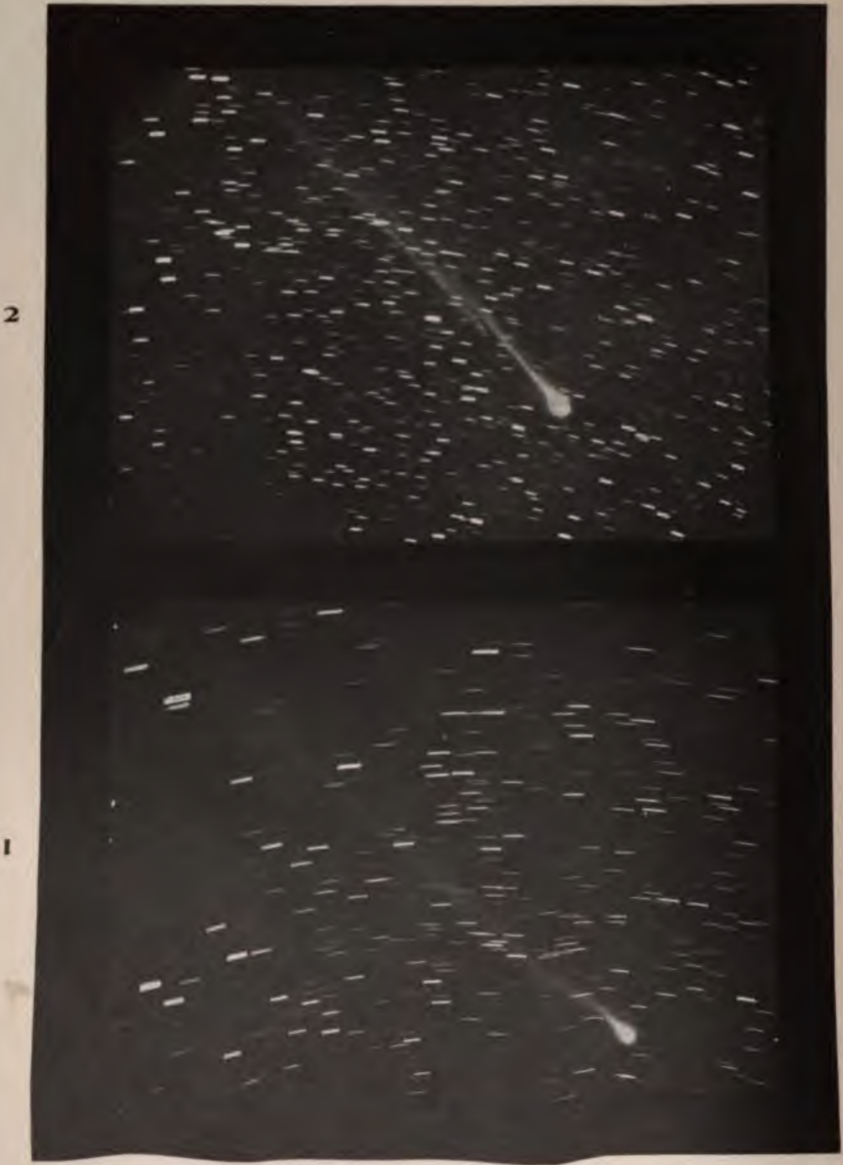
It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)



Comet *c* 1903 (BORRELLY)

From negatives by R. J. WALLACE

1. 1903 July 22: 12 hr. 1 m.—14 hr. 31 m. Cent. St. Time
2. " " 24: 11 hr. 59 m.—14 hr. 29 m. " "

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PHOTOGRAPHS OF COMET *c* 1903 (BORRELLY).

BY R. J. WALLACE.

Through the courtesy of Professor E. E. BARNARD, the writer was privileged to make use of the camera and lens used by him for the purpose of continuing the series of negatives of Comet *c* during a portion of the month of July, which portion of time was fortunate enough to embrace the most interesting period of the comet's career, at least from a pictorial point of view.

The lens referred to is that belonging to a projection lantern manufactured by the Mackintosh Optical and Battery Company, of Chicago, and is the property of Director GEORGE E. HALE. Being of short focus with relatively large aperture,—viz., 1.6 inches diameter, with 6.3 inches focus,—it thus gives a wide field of fairly large area upon the plate and with excellent definition.

Upon the date of July 20th a negative taken by the writer shows clearly the tail extending to about 9°, single, and with no particular structure (exposure-time, 2^h 25^m), while that upon the evening following is not distinguished by any particular change (exposure-time, 2^h 15^m).

On the plate of July 22d a distinct change was observable, in that the tail had split up into four separate streamers, emanating from the head and trailing off into space with varying lengths readily measurable from 6°.5 to 16°. The exposure-time was 2^h 31^m, with a fairly good sky.

The negative of the ensuing evening (July 23d) was marked by a division of the tail into three, one of which was very faint but yet distinctly traceable, and extending to a distance of about 14°. Exposure-time, 2^h 2^m with a fair sky.

The record of the 24th showed a marked change, the tail having the appearance of being broken off transversely at a distance of 3° or 4° from the head, the inclination of the following division differing by about 2° from the direction of the longitudinal axis of that preceding. That this separation was taking place at a very rapid rate is shown by the negative of Professor BARNARD of that same evening, and preceding that of the writer by a mean of $3^h\ 0^m$, wherein the separation is shown very decidedly but only about 0°.3 wide, as against 0°.5 in the later negative.

Such a phenomenon was naturally the cause of much anticipatory interest in the results of the following evening, but by that time (according to a negative by Professor BARNARD) the tail had apparently completely coalesced, and from then on there is nothing recorded of unusual interest.

It may further be mentioned that prints from all pairs of negatives taken by Professor BARNARD and the writer, when properly matched, give perfect stereoscopic effect when so viewed, the comet hanging suspended considerably in front of the stars, and the structure of the tail clearly showing. Lack of space prevents the reproduction here of such a print.

All negatives were made upon Seed 27 gilt-edge plates, backed, reduced with hydrochinon liberally restrained with bromide, carefully shielded from the dark-room light, and developed until the appearance of chemical fog indicated the maximum effect.

YERKES OBSERVATORY, September 25, 1903.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1903.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon,	Nov.	4,	$9^h\ 27^m$ P.M.	Full Moon,	Dec.	4,	$10^h\ 13^m$ A.M.
Last Quarter,	"	11,	6 46 P.M.	Last Quarter,	"	11,	2 53 A.M.
New Moon,	"	18,	9 10 P.M.	New Moon,	"	18,	1 26 P.M.
First Quarter,	"	26,	9 37 P.M.	First Quarter,	"	26,	6 22 P.M.

The Sun reaches the winter solstice and winter begins December 22d, 4 P.M., Pacific time.

Mercury is a morning star at the beginning of November, having passed greatest west elongation about a fortnight before. It rises about an hour before the Sun, and may possibly be seen under good condition of weather; but it begins to approach the Sun quite rapidly, and comes to superior conjunction on November 21st. It can therefore be seen as a morning star for only a very few days. After conjunction it swings slowly away from the Sun, as an evening star, and toward the close of December it is well out toward greatest east elongation. On December 31st it remains above the horizon an hour and a half after sunset, and for a week or so earlier the interval is more than an hour. The conditions for visibility are fairly good for the last week of December.

Venus is in fine position for observation as a morning star. It is still bright enough at the beginning of November to be seen by the naked eye in full daylight, and on November 28th it reaches its greatest west elongation, 46° 46′ from the Sun. It then rises four hours before sunrise; and at the beginning of November and the end of December the interval is only half an hour less. It moves about 60° eastward and southward among the stars, from the eastern part of *Leo* through *Virgo* and *Libra* nearly to *Scorpio*. *Venus* is in perihelion on December 11th, but, on account of the almost perfect circularity of its orbit, the variation in distance from the Sun is very small.

Mars is still an evening star in the western sky after sunset. Throughout November and December it remains above the horizon about three hours after sunset, and the interval changes only a few minutes in the two months. During this time the Sun gains about 15° on the planet in their common eastward motion; but during December the planet runs northward more than the Sun, and this keeps the interval between the setting of the Sun and of the planet about the same. *Mars* moves about 49° eastward and 7° northward among the stars, from the western part of *Sagittarius* to the eastern part of *Capricorn*. It is in perihelion on December 22d, and its distance from the Earth in millions of miles increases from 167, on November 1st, to 179, on December 1st, and 190, on December 31st. The diminution is not quite as rapid as it was during the early autumn, and it will keep on slowing up until the maximum is reached, in the spring of 1904. There will be a loss of about thirty per cent in brightness during the two months, and *Mars* will no longer be conspicuous; but it will still be as bright as a small, first-magnitude star, and easily identified in the comparatively barren region in which it is moving.

Jupiter is in fine position for observation in the southern and southwestern sky in the evening. On November 1st it does not set until nearly 2 A.M., on December 1st at midnight, and on December 31st shortly after 10 P.M. It moves very slowly westward until November 9th, and then resumes its direct eastward motion. By the end of December it has moved 4° eastward and 2° northward. It is in the western part of the constellation *Pisces,* and very few naked-eye stars are near it. At the end of December the vernal equinox is about 10° east and 6° north of *Jupiter,* and the planet will pass near that point of the heavens in the spring of 1904.

Saturn is also in the southwestern sky in the evening, but much lower down than *Jupiter*, although it may be seen without difficulty in the evening sky until the end of December. On November 1st it sets at about 10:30 P.M., at 8:40 on December 1st, and at about 7 on December 31st, the last being rather more than two hours after sunset. It is in the constellation *Capricorn,* and its motion among the stars is 5° eastward and 1° northward. Toward the close of December it is in the neighborhood of *Mars*, and there will be an interesting conjunction of the two planets on the evening of December 20th. *Mars* will pass to the south of *Saturn* from west toward east, at a distance just a trifle more than the apparent diameter of the Moon. At the time of nearest approach, the Moon, about two days old, may be seen between the planets and the western horizon.

Uranus is low down in the southwestern sky on November evenings,—too low for so faint an object to be easily seen. It passes conjunction with the Sun on December 18th, and becomes a morning star. During November and December it moves about 3° eastward into the extreme western part of *Sagittarius.*

Neptune comes to opposition with the Sun early in the morning of December 27th.

NOTICES FROM THE LICK OBSERVATORY.*

Prepared by Members of the Staff.

Notes on Some Interesting Double Stars.

Among the many interesting double stars on my observing list, the following seem worthy of special mention at this time. Nearly all of them belong to the class of rapid binaries, though in several instances we lack the data necessary for computing an orbit. All the observations here referred to were made with the 36-inch telescope, using eyepieces with magnifying powers of from 1000 to 2600, except those of 70 *Ophiuchi* and three of the measures of ζ *Herculis* in 1902, which were made with the 12-inch.

Ho. 212 = 13 Ceti.—The mean of three measures in 1902 is:—

1902.63   286°.0   0″.26

and of two recent ones:—

1903.59   306°.2   0″.18

Recalling the fact that Burnham did not see the close pair in 1877 when he measured a faint distant companion, nor in 1890-91 when he examined it with the 36-inch, and noting that the angular motion seems now to be increasing, with diminishing distance, it seems very possible that the revolution period may be about fourteen years. It is now a difficult object to measure even with the 36-inch telescope.

β 612.—The mean of two nights' measures made last year is:—

1902.32   249°.2   0″.17

and of five measures in the present year:—

1903.39   261°.2   0″.15

From a comparison of these results with earlier measures, it appears that the period is not likely greatly to exceed thirty years, the value found by GLASENAPP in 1892. It will be a difficult pair to measure for several years to come.

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* Lick Astronomical Department of the University of California.

β 949.—This is another star that is now in a critical part of its orbit. When discovered by BURNHAM, in 1880, the distance was 0″.62. In 1898 I found that the distance had diminished to 0″.41. The distance has since diminished very rapidly, with comparatively little change in the angle. The star was examined on three fairly good nights during the present year, but was found too close to measure, the distance being little, if any, over $^1/_{10}$″. The plane of the orbit is apparently nearly in the line of sight.

Σ *2084 = ζ Herculis.*—This well-known binary has now become an easy pair, and the motion for some years will be comparatively slow. My measures for the last two years are:—

1902.46	215°.1	0″.92	4^n
1903.34	204 .4	1 .05	2

Σ *2272 = 70 Ophiuchi.*—My measures for the past two years give:—

1902.60	212°.3	1″.59	5^n
1903.54	196 .7	1 .75	3

The point of minimum apparent distance was passed early in 1901, and the distance is now steadily increasing with a corresponding decrease in angular motion.

A. 88.—The rapid angular motion of this pair continues, and the period is likely to be a short one. The mean of three recent measures is:—

1903.44	298°.4	0″.11

The position at the time of discovery was:—

1900.46	353°.2	0″.14

Winlock = ζ Sagittarii.—This interesting binary has now became an exceedingly difficult object for observers in the northern hemisphere, and in the southern hemisphere, unfortunately, there are practically no observers interested in double stars who can command telescopes powerful enough to resolve it. The following are, so far as I know, the only measures made in the past two years:—

1902.55	51°.7	0″.43	1^n	INNES.	(Communicated by letter.)
1902.66	47 .6	0 .36	2	AITKEN.	
1903.40	16 .5	0 .22	2	AITKEN.	

O Σ *535* = δ *Equulei.*—In No. 87 of these *Publications* (p. 198) I gave my measures of this pair to 1902.794. Since then I have measured it as follows:—

1902.873	35°.2	0″.16	
.969	30 .6	0 .18	
1903.46	28 .3	0 .28	5^n

The gradual increase in the angular distance which was observed the latter part of last year has evidently continued, and the star is now easily resolved with the 36-inch,—in fact, it is readily recognized as a double star with the 12-inch. Assuming the period of 5.7 years as correct, it will remain a comparatively easy pair for the next two years, and will then close in again.

β *989* = κ *Pegasi.*—Like the preceding pair, κ *Pegasi* will soon reach its greatest apparent separation, and will be well placed for observation for several years. My recent measures give the following results:—

1901.970	209° ±	0″.07 ±	1^n
1902.92	171 .8	0 .14	2
1903.52	139 .5	0 .14	4

A. 417 = *83 Aquarii.*—In announcing the discovery of this pair in these *Publications* (No. 86, p. 166) the value of the annual proper motion was erroneously given as 0″.023 in 17°.5. It should be, as Professor Burnham kindly pointed out to me, 0″.107 + in 78°. The same correction applies to *L. O. Bulletin* No. 29 (p. 24). This motion is certainly common to both components, and the system is therefore a physical one. My measures also seem to indicate direct orbital motion, the mean of four recent measures being:—

1903.62	73°.2	0″.20

as compared with:—

1902.64	61°.0	0″.19	4^n

β *80.*—This is one of the most interesting stars in Burnham's catalogue, and, at present, a very difficult pair to measure. The distance is rapidly diminishing, and data for an orbit will soon be available. My measures are:—

1901.88	9°.6	0″.32	2^n
1903.65	47 .2	0 .20	2

β 733 = 85 Pegasi.—The angular separation in this pair is still great enough to make the little companion easily visible under favorable conditions. Three recent measures give:—

1903.54 262°.0 . 0″.76

The computed position from BURNHAM's orbit for the same date is: 267°.9, 0″.72.

September 10, 1903. R. G. AITKEN.

PERSONAL SCALE.

Dr. SCHLESINGER's note on this subject in No. 91 of these *Publications* is of interest to all who are engaged in work involving the use of micrometer-screws. For the sake of comparison, I have thought it might be worth while to give here the results of a similar count I have made of the number of times each tenth was recorded in 1,200 recent readings of the micrometers attached to the 36-inch and 12-inch telescopes, together with the results of a similar count of 1,000 earlier readings. As the milled heads of the micrometer-screws are divided into one hundred parts, the tenths of divisions here considered have the value of thousandths of one revolution. The personal scale, therefore, does not affect the accuracy of the micrometer measures. In the following table all of the percentages would be 10.0 if there were no personal scale.

Tenths.	1200	1000
.0	20.2	20.3
.1	8.2	8.9
.2	16.7	15.7
.3	8.0	8.4
.4	6.8	7.8
.5	9.2	11.0
.6	5.9	6.7
.7	5.3	3.0
.8	15.3	14.6
.9	4.4	3.6

It is apparent that the two counts give practically the same error-curve, and show that while 0.5 was read as often as it occurred, 0.1, and especially 0.9, were slighted in favor of 0.0; and 0.3, 0.4, and 0.6, 0.7 in favor of 0.2 and 0.8 respectively.

September 8, 1903. R. G. AITKEN.

DISCOVERY OF A NEW COMPANION TO OΣ 499.

In the course of my survey of the stars in the zone + 56° to + 60°, I turned the 36-inch telescope upon OΣ 499 on the night of June 11, 1903, and found that the fainter star of this wide pair was a close double.

Three nights' measures of the new pair give:—

1903.54 146°.6 0″.42 9.0-10.8 magnitudes.

The wide pair is probably fixed, having shown no motion since discovery in 1847.

September 10, 1903.

R. G. AITKEN.

REDISCOVERY OF COMET 1889 V, 1896 VI (BROOKS).

The first observation of BROOKS's Comet during the present apparition was secured with the 36-inch telescope on August 18th, 12^h 17^m 23^s Mt. Hamilton M. T., at which time it was found in R. A. 21^h 2^m $51^s.30$; Decl. — 27° 4′ 18″.8. The position predicted for this date by Professor NEUGEBAUER differs from the observed place by but little more than 5′. The comet is therefore following the predicted path very closely.

This comet is of unusual interest for several reasons. At the time of its first appearance, in 1889, it was attended by several companions, one of which at times rivaled its primary in brightness. It is also interesting because of its possible identity with the lost LEXELL's comet, and because it is the only comet that has been observed at two consecutive oppositions, Professor BARNARD having secured five observations of it between November 22, 1890, and January 13, 1891,—a year and a half after its discovery.

On its second return to the Earth it was first observed by M. JAVELLE, at Nice, on June 20, 1896, and was followed by observers at fourteen stations until February 25, 1897, when Professor HUSSEY secured the last observation, with the 36-inch telescope.

Professor BAUSCHINGER determined the definitive elements from the observations in 1889-91, and later revised his work with the aid of the observations made in 1896-97. These elements, with corrections applied for perturbations, afforded the basis for the ephemeris which Professor NEUGEBAUER computed for the present apparition.

The companion comets were not observed in 1896-97, and no trace of them could be seen with the 36-inch this year.

It may be added that Giacobini's periodic comet (1896, V) has so far escaped detection on its present return, though it is favorably situated, according to theory, and has been carefully searched for with both the 12-inch and the 36-inch telescopes.

The two other periodic comets that are now in the neighborhood of the Sun, Faye's well-known comet and Perrine's comet (1896, VII), are very unfavorably placed, and the dense banks of smoke and haze that have hidden our horizon for some weeks have prevented any effective search for them.

September 22, 1903. R. G. Aitken.

Observations of the White Spot on *Saturn*.

The following observations of the white spot on *Saturn* were made with the 36-inch refractor, in the course of other work. No attempt was made to observe the spot systematically.

1903, July 17.—Spot transited planet's meridian at 23^h 31^m 15^s Gr. M. T. Equatorial diameter of spot (observed), 1″.25; polar diameter of spot estimated to be two thirds of the equatorial diameter. Power, 520.

1903, August 23.—17^h 18^m Gr. M. T. Spot estimated to be 1″ past the planet's meridian. The spot is larger and more conspicuous than on July 17th. The spot is divided by a very narrow dark east-and-west belt. C. D. P.

September 17, 1903.

Visual Observations of the Spectrum of *Nova Geminorum* Made with the 36-Inch Refractor.

The spectrum of *Nova Geminorum* was observed visually with the one-prism spectrograph on the mornings of August 17th and 18th. The star was invisible in the finder, so that no estimate of magnitude could be made. Nothing could be made out either at H_α or D. The three chief nebular lines were, however, very well developed, that at H_β being faint, λ 4959 somewhat stronger, and that at λ 5007 very much more intense. There was probably also a very faint line visible near λ 4700, but too faint to identify with accuracy. The lines seemed sharp and well-defined. A plate of this region taken on April 6, 1903, (cf. *L. O. Bulletin*, No. 37,) showed a faint trace of the line at λ 5007, probably just beginning to appear. At present this line is far the most conspicuous, and in it is concentrated practically all the light of the visual spectrum. The change to the nebular type seems complete.

Heber D. Curtis.

Publications of the Lick Observatory, Volume VI.—Meridian-Circle.

This volume, which is now being sent out to the correspondents of the Lick Observatory, contains the results of Professor Tucker's observations with the meridian-circle during the period August, 1896, to March, 1901. The observations include the following schemes of work: The Declinations of the Bethlehem Latitude Stars; Additional Standard Close Circumpolar Stars; Zodiacal Stars for Heliometer Measures of the Major Planets; The Southern Stars of the Catalogue of Piazzi; The Reference Stars for the Photographs of *Eros;* and Miscellaneous Observations, including those of *Eros, Nova Persei,* comets, and comparison-stars.

Corrections to Asteroid Ephemerides.

Asteroid observations made with the 12-inch equatorial give the following corrections to ephemerides published in *Veröffentlichungen des Rechen-Instituts,* No. 21:

(333)	*Badenia*	-25^{s}	$-3'.0$
(332)	*Siri*	$+60$	$+8.6$

James D. Maddrill.

GENERAL NOTES.

Some Common Inaccuracies in the Application of the Method of Least Squares.—It is gratifying to notice how wide-spread has become the use of the method of least squares during recent years. When the method was new it found favor only in astronomy and geodesy. Nowadays it is not only used in all kinds of physical problems, but one is no longer surprised to see it applied to problems in biology, in psychology, and even in sociology. Perhaps because of this wider field, or perhaps because of the pitfalls inherent to any branch of mathematical probability, it is certainly true that there are too many errors in current work of this kind. One might suppose that astronomers, with whom the subject is a century old, would be open in small degree to this criticism. But it appears that some are content to learn how to use the method without showing any great curiosity regarding the underlying principles. It may not be without value to point out some common inaccuracies and errors that the writer has noticed.

In a recent number of the *Astronomische Nachrichten* we read the following definition: "The probable error means that where no force is at work the result will probably differ from zero by just this amount." Evidently this is a recurrence of the time-honored confusion between probable error and "most probable error." The former is such that the chance for the real error exceeding it is just equal to the chance of the real error being less than it; or, otherwise stated, if p be the probable error of an observed quantity, m, then there is an even chance that the true value of m lies between

$$m - p \qquad \text{and} \qquad m + p$$

The "most probable" error is always zero, for this is only another way of stating a fundamental assumption, that large errors are less likely to occur than smaller ones.

It should be noticed that there is another definition of probable error,—namely, that implied in the expression

$$\pm 0.6745 \sqrt{\frac{[vv]}{n\,(n - 1)}}$$

which is not quite identical with the former. The two approach equality only when n, the number of observations, becomes large. For example, if $n = 2$ the formula gives as the probable error of the mean about *one third* of $(m_2 - m_1)$, m_2 and m_1 being the two observations. It is easy to see, however, that the former definition leads to *one half* of $(m_2 - m_1)$ as the probable error. For we may have four cases, all equally likely to occur:—

(1) m_1 and m_2, each greater than the true value.
(2) m_1 greater, and m_2 less than the true value.
(3) m_2 greater, and m_1 less than the true value.
(4) m_1 and m_2, each less than the true value.

Consequently, there is just an even chance that the true value lies between

$$\frac{m_2 + m_1}{2} - \frac{m_2 - m_1}{2} \text{ and } \frac{m_2 + m_1}{2} + \frac{m_2 - m_1}{2}$$

According to the *former definition,* then, $\frac{m_2 - m_1}{2}$ must be the probable error of the mean.*

A misleading practice that one sees quite often is exemplified by the following. Suppose we have three determinations of a quantity with their probable errors:—

$$100 \pm 1$$
$$110 \pm 3$$
$$120 \pm 2$$

which we desire to combine into a final value. It is quite usual for the computer to obtain the weights from the indicated probable errors and to combine the three determinations accordingly into

$$104.5 \pm 0.86$$

This process ignores the existence of systematic errors (which in this case are so evidently present), and the result is open to criticism on two accounts: first, the adopted mean is not the best that can be gotten from the data; and, second, the probable error given is misleadingly small. Far more businesslike would it be to take the simple mean of the three determinations and to estimate the probable error at 4 or 5.

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* A rough but very convenient way of estimating the probable error of the mean of a small number of observations (not over five or six) is to divide twice the range by three times the number of observations. By the *range* we mean the difference between the greatest and the least of the observed quantities. This will usually give a sufficiently close approximation to the expression $0.6745\sqrt{\frac{[v\,v]}{n\,(n-1)}}$.

Another irritating practice is the loose employment of the word "uncertainty." Thus, one astronomer, after computing a probable error of 0″.012, states that the quantity to which it is attached "is subject to an uncertainty of perhaps 0″.02." It is doubtful whether this writer could say what he means by "uncertainty," and surely the word will convey nothing definite to his readers. This usage should be abandoned, at least until a precise definition is given to the word; and even then it would be inadvisable to use it, for we already have two errors in common use, the *mean* and the *probable,* to indicate the reliability of a quantity. It would be convenient if one of these two could be employed to the exclusion of the other, for now it is necessary to specify which is being used in each particular case. German astronomers lean toward the mean error, and Americans toward the probable. The former obviates the necessity of multiplying by 0.6745; but this small advantage is outweighed, in our opinion, by the fact that the probable error has a concrete definition. Any person of fair intelligence can understand what probable errors are, even though he knows little of mathematics. The mean error, on the other hand, has an exceedingly technical definition. However, if one of these errors could be universally adopted, it would be a matter of small importance which should prevail.

Probably owing to the example set by GAUSS, it was formerly usual to give probable and mean errors to four or five significant figures. This practice has greatly decreased, but it has not entirely disappeared. In many cases two figures are ample, and it is difficult to imagine a case where more than three could be defended.

An error more serious than any of the above came under the writer's notice some time ago, and since then he has seen several other examples of it. The principle involved does not seem to be referred to in any of the standard works on the subject. Suppose we have a number of observation equations (equations of condition) involving several unknowns. Let these be solved by the method of least squares, and the resulting values of the unknowns be substituted in the original observation equations, giving the residuals in the usual way. Now, considering each of the residuals in turn, it may be small for either of two reasons: first, because the corresponding observation was an accurate one; or, second, because of the way in which the coefficients of the unknown quantities enter. For example, if one of the unknowns rests for its determination principally upon only one of the observation-equations, then the residual for that equation will inevitably be small. The error to which the writer wishes to call attention results from the neglect of the possibility of a residual being small for any other reason than that the observation was an accurate one. A numerical example will make this clearer. We will suppose that we desire to find the declination (δ_0) at 1830 and the proper motion (μ) of a star which has been observed in 1800, 1830, 1840, and 1850. Assuming as a first approximation that all four observations are equally good, we solve by the method of least squares and compute the residuals:—

$$\begin{aligned} v_1 &= \delta_0 - 30\,\mu - \delta_1 \\ v_2 &= \delta_0 \qquad\quad - \delta_2 \\ v_3 &= \delta_0 + 10\,\mu - \delta_3 \\ v_4 &= \delta_0 + 20\,\mu - \delta_4 \end{aligned}$$

Suppose similar computations have been made for many other stars observed at the same dates, and that it is found that the average residual for the observations made in 1800 is about equal to the average residual for any of the three other dates. It would be a gross error to conclude from this that the observations made in 1800 are equally accurate with the others (yet just this has been done by some astronomers), because the proper motions depend so largely on the earliest observation that, other things being equal, we are bound to get small residuals for that date. It is not the writer's intention to go into the details of this point in this place. It will suffice to say that it is possible to compute the ratio between the actual errors of observation and the residuals, for any given set of equations. In the example above, these are respectively for the four equations, 0.11, 0.75, 0.68, and 0.46. If the residuals came out on the average proportionate to these ratios, then only could we conclude that the observations were of equal weight.

One other kind of error deserves mention before closing this note. In writing down our equations of condition we should be careful to let the measured quantities appear just as we observe them. Thus, suppose we desire to find x and y from equations of the form

$$\begin{gathered} x + n_1 y = m_1 \\ x + n_2 y = m_2 \\ \text{etc., etc.} \end{gathered}$$

These equations are evidently equivalent to

$$\begin{gathered} y + a_1 x = b_1 \\ y + a_2 x = b_2 \\ \text{etc., etc.,} \end{gathered}$$

where $n_1 = \frac{1}{a_1}$, $n_2 = \frac{1}{a_2}$, etc.; and $m_1 = \frac{b_1}{a_1}$, $m_2 = \frac{b_2}{a_2}$, etc. In general, these two sets of equations, if solved by the method of least squares, will give two different values for x and two for y. The first set should be used if m_1, m_2 were observed, and the second set if b_1, b_2 were observed. Other examples can be constructed in which the fallacy is not quite so apparent as in the above. For an actual case the reader is referred to *Nature* (Vol. 63, page 489). FRANK SCHLESINGER.

Example of Personal Scale.—In connection with the note which appeared in the last number of these *Publications*, Mr. J. A. PARKHURST has kindly communicated the results of two counts: (1) of 1022 readings of a photometer scale; and (2) of 1148 readings of a micrometer. The first column below gives the estimated tenth; the other columns are percentages of the whole:—

	First Count. (Per cent.)	Second Count. (Per cent.)	Mean. (Per cent.)
0	17·5	14.0	15·7
1	7.1	10.3	8.7
2	12.0	11.9	12.0
3	9·7	9·4	9.6
4	6.2	5·3	5·8
5	7·4	8.1	7·8
6	4·5	6.4	5·4
7	11.3	9.8	10.5
8	10.9	13.0	14.0
9	7·4	11.8	9.6

This observer's scale is well pronounced and very symmetrical, the only exception in the latter respect being that 8's are preferred to 2's. F. S.

During 1903 four doctorates in astronomy were granted by universities in this country. This is equal to the average for the five preceding years. The recipients of these four degrees and the titles of their theses are: W. A. HAMILTON (University of Chicago), *On the Convergency of the Series in the Determination of the Elements of Parabolic Orbits and the Errors Introduced in the Elements by Imperfections of the Observations;* H. K. PALMER (University of California), *An Application of the Crossley Reflector of the Lick Observatory to the Study of Very Faint Spectra;* JOEL STEBBINS (University of California), *The Spectrum of o Ceti;* J. P. McCALLIE (University of Virginia), *A Problem in Periodic Orbits, Second Order Perturbations of Jupiter and Saturn, Independent of the Eccentricities and of the Inclinations.*

From various sources, principally *Science,* we gather the following items: Dr. BURT L. NEWKIRK, a graduate ('97) of the University of Minnesota, has been appointed a computer on the orbits of the Watson asteroids at the University of California. Doctor NEWKIRK obtained his Ph.D. last year at Munich, his thesis being a photographic determination of the parallax of the central star in the annular nebula in *Lyra.*——Dr. CHARLES S. HOWE, Professor of Astronomy at the Case School of Applied Science, has been appointed president of that institution.——Professor E. C. PICKERING and Sir WILLIAM HUGGINS are among those who received honorary doctorates at the recent celebration at the University of Heidelberg.——Mr. ARTHUR R. HINKS, well known for his work in astronomical photography, has been promoted to the chief observership at Cambridge Observatory, England, in the room of Mr. GRAHAM, who has retired at an advanced age. Mr. W. E. HARTLEY has been appointed to the post made vacant by Mr. HINK'S promotion.——M. LEBOEUF has been appointed Professor of Astronomy at the University of Besançon.——Professors H. H. TURNER (of Oxford) and W. KAPTEYN (of Utrecht) have accepted invitations to visit this country as representatives of astronomy at the congress which is to be held at the St. Louis Fair. Among the mathematicians who have accepted similar invitations is POINCARÉ.——H. L. SMITH, Professor of Astronomy and Physics in Hobart College, died on August 1st.

Prosper Henry, astronomer *adjoint* at the Paris Observatory, died on July 25th, at Pomogen in the French Alps, as a result of exposure to extreme cold. The two brothers, Prosper and Paul, have been connected with the Paris Observatory for nearly forty years, and have taken a great part in the recent work of that institution. It is said that there is not an instrument in the observatory that the Henrys have not made or remodeled. Very rarely has one of the brothers published anything apart from the other, and their work is so interwoven that probably no one knows just what is due to the one and what to the other. An illustration of this will be found in their discoveries of minor planets. The first of these is credited to Prosper, the next to Paul, the next to Prosper, and so on through the whole fourteen. The Henrys will no doubt be remembered longest for the share they took in bringing about the Astrophotographic Catalogue. Their other important work consists in the making of lenses and plane mirrors, asteroid discoveries, discovery of nebulæ in the *Pleiades*, method for reducing photographic star positions, and many other researches in astronomical photography.

F. S.

On May 2, 1903, ground was broken for the erection of a new observatory at Amherst College. The plans contemplate a structure one hundred and fifty feet long, east and west, surmounted by three domes, the central one to contain an equatorial refractor with a lens eighteen inches in diameter. This telescope is now in the process of construction by the Alvan Clark & Sons Corporation.

Number III of volume XLVIII of the Annals of Harvard College Observatory, containing a Provisional Catalogue of Variable Stars, forms a very welcome addition to variable-star literature. The last preceding catalogue, Chandler's third, was published in 1896, and, as the number of variable stars has increased largely since that time, it had become impossible, unless one kept up a card catalogue, to keep properly informed of the advances in this work.

Schönfeld's first catalogue (1865) contains 113 stars;

CHANDLER'S third catalogue (1896), 393 stars; while in the present catalogue 1,227 stars are included, 509 of which, however, are the variables discovered by Professor BAILEY in clusters. In constructing this catalogue Professor PICKERING has departed from the guiding precepts used for other catalogues, and has included many stars whose variability has not yet been confirmed, claiming that it is better to include some stars not variable (definite names having not yet been assigned) than to exclude some which are variable. This position is certainly correct, especially for a provisional catalogue. One of the chief uses of a variable-star catalogue is to guide the observer in making up the observing list. It should therefore contain, in my opinion, not only a list of the certainly recognized variables, but a list, preferably, supplementary, of all stars ever suspected of variability, even though observations may have shown that for a considerable length of time the star was constant in light.

A new form of designation has been introduced into the catalogue, consisting of six figures which give the approximate position of the star. The first two figures are those of the hour, and the next two those of the minutes of Right Ascension of the star for 1900. The last two figures give the degree of Declination. South Declination is indicated by printing the figures in italics. The designation of the first star of the catalogue is *000339*, which means R. A. 0^h 3^m, Dec. — 39°. In defense of this system Professor PICKERING states as follows: "A new form of notation is proposed with much hesitation, but it has been found so convenient in actual use here that it has been retained. It aims to furnish a distinctive designation for any star, which will not be too long to be readily retained in the memory, and yet will give the position with sufficient precision to give the approximate setting for a visual or photographic telescope, or to decide whether the object is conveniently situated for observation."

It might be stated, however: *First.* It is not at all certain that six figures can be readily retained in the memory for any considerable length of time,—for instance, while one is making observations of the variable. I believe it will be generally admitted that the average person of astronomical training will retain four figures without effort. But when the number of figures reaches six, I believe that, in general, a distinct mental effort will be necessary to retain them. Any one accustomed to using logarithms knows how much more mental effort is required in using six-place tables than in using four-place tables, although of course considerable of this added effort comes in making the interpolations.

Second. If the observer is working with a telescope larger than four inches, he will desire for setting purposes a declination more accurate than the nearest degree.

Third. It will be necessary for the observer in recording observations to adopt some symbol to denote South Declination. This will require added effort, and the omission of the symbol may lead to confusion between north and south stars. It should be stated, however, that this last is a theoretical rather than a practical objection, for in the catalogue under consideration there are only two instances of two stars, one north and one south, having the same designation.

Fourth. It will very seldom happen that one will have at hand the designation of the variable and not its coordinates also; and if one wishes to see whether or not the star is in position for observation, it will be more convenient to refer to the columns of Right Ascension and Declination than to the designation-number.

Fifth. Although good for a great many years, the position given in the designation-number, because referred to the epoch of 1900, would ultimately not be sufficiently exact for setting purposes. Our successors of the twenty-first and following centuries may get tired of referring to the epoch of 1900.

CHANDLER's system of designating variable stars has been pretty generally adopted, and should be retained, I believe, until one is proposed which is distinctly and unmistakably better.

The new catalogue contains two columns not found in CHANDLER's catalogues. The one gives the class to which the variable belongs, the classification being that proposed by Professor PICKERING in 1880; the other designates the spectrum of the variable, the notation employed being the same as that used in the DRAPER catalogue.

Copious notes and several supplementary tables follow the catalogue.

An examination of this catalogue reveals the vast amount of work that variable-star observers have before them. Some of the columns are conspicuous for their incompleteness. There are listed in the catalogue, excluding new stars and variables in clusters, 286 stars whose periods are only approximately known or wholly unknown.

S. D. T.

PUBLICATIONEN DES ASTROPHYSIKALISCHEN OBSERVATORIUMS KÖNIGSTUHL-HEIDELBERG, HERAUSGEGEBEN VON DR. MAX WOLF. ERSTER BAND. KARLSRUHE, G. BRAUN. 1902.

This interesting volume is the first of the publications of this observatory under its new régime. Wisely limiting itself to one chosen field, the observatory has produced a volume which entitles it to a high rank as an institution of definitely concentrated research. A full description of the buildings and instruments is left for a subsequent volume. Provided as it is with two Voigtländer 6-inch cameras and the two great 16-inch Bruce photographic lenses, the Königstuhl Observatory is singularly well equipped for stellar and planetary photography. It is unnecessary here to mention Dr. WOLF's successful work on the asteroids.

As a field in which comparatively little has been done, the Königstuhl Observatory has fixed upon the photography and accurate cataloguing of nebulæ as its main work, and it is to this subject that the present volume is largely devoted. A rapid and accurate method was needed to measure the positions of the large number of small nebulæ discovered photographically, and a parallactic measuring-engine on the lines proposed by KAPTEYN was procured. In connection with the First Königstuhl List of 154 Nebulæ, a description of the instrument is given by Dr. WOLF, with an investigation of the errors of the screws and circles. The method of the parallactic measuring-engine is, in brief, as follows: Let us suppose the measuring-microscope to be mounted as a small equatorial and the photographic plate to be placed at a distance from it equal to the focal length of the lens with which it was taken. Then, if the photographic plate is placed in a position which, as seen from the little measuring-equatorial, is of the same hour-angle and declination as was the region of the sky at the time of the exposure, we can with the equatorially-mounted microscope read off the positions of objects directly in differences of Right Ascension and Declination, much as would be done with an equatorially-mounted telescope fitted with a filar micrometer. In practice the equatorially-mounted microscope is placed with its polar axis horizontal, and is provided with a third vertical axis for convenience.

Dr. SCHWASSMAN, after treating very fully the theory of the apparatus, has used it in the preparation of the Second Königstuhl List of 301 Nebulæ, employing the full and rigorous methods demanded by the theory in the case of plates of large area. This second list contains the positions for 1900 of 301 nebulæ in *Virgo*. The employment of the full formulæ must have consumed a very great deal of time in both measurement and reduction, and such refinement would seem entirely unnecessary in objects of the definition of an ordinary nebular patch, and in plates of this area, where the images of ninth-magnitude stars are about 47″ in diameter. Dr. SCHWASSMAN finds for the mean error of a position

$$m_\alpha = \pm 0^s.16 \qquad m_\delta = \pm 1''.8$$

and a comparison with micrometer results shows that the accuracy of the coordinates in Right Ascension is of the same order of magnitude as that of direct micrometer measures, while the accuracy in Declination is slightly inferior.

In a later paper in the same volume Dr. WOLF gives the Third Königstuhl List of Nebulæ, comprising 1,528 nebulæ near the pole of the Milky Way. By using more approximate methods, and neglecting the full and rigorous formulæ of KAPTEYN'S method, a great saving of time was effected without appreciable loss of accuracy. Dr. WOLF estimates the error of a position in the third list as somewhat larger than $0^s.1$ and $1''.0$. As to the time consumed, about eighty-two hours were spent in the actual measurement, so that the positions of 1,528 nebulæ to the above degree of accuracy were secured in a few weeks, whereas had the full and rigorous method employed by Dr. SCHWASSMAN been used it would have been several years. Of these 1,528 nebulæ only one in nineteen, or about five per cent, were previously known, confirming KEELER'S conclusions (*Astrophysical Journal,* vol. XI, p. 325) as to the enormous number of these small objects. A map is given showing the density of the grouping of these nebulæ about the pole of the Milky Way, and Dr. WOLF states that he knows of no other region where nebulæ are so thickly clustered, there being at the densest portion no fewer than seventy in one sixteenth of a square degree. Another point of interest brought out in this investigation is, that the large majority of the position-angles of the axes of "long" nebulæ are grouped about 60°.

Dr. CARNERA investigates the light-curve of the variable star *S Leonis* by photographic methods. The method used was that of the measurement of the diameters of the star-disks on the photographic plates. Numerous precautions were taken to avoid the errors which may so easily arise in this method, and plates were taken of the region of the variable, the *Pleiades,* and the Pole at the same angle of elevation above the horizon. CHANDLER'S period and light-curve is confirmed. Dr. CARNERA gives also a number of photographic positions of *Eros.*

Mr. A. KOPFF, in an interesting paper, gives an investigation from the negatives of two regions of the phenomenon, first noted by HERSCHEL, that the regions about many nebulæ are relatively starless. The regions investigated are those about the Nebula in *Orion* and the great "America" Nebula. A count of the stars was made, showing that each of these is surrounded by a veritable star-desert, the *Orion* Nebula lying near the northwest and the America Nebula near the northeast end of the relatively starless tracts surrounding them.

H. D. C.

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
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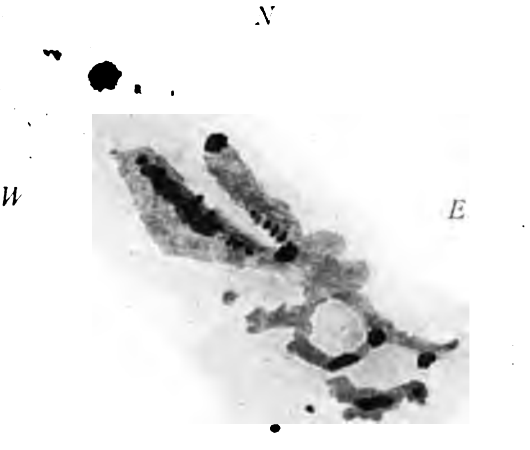
THE GREAT SUNSPOT OF OCTOBER, 1903.

By ROSE O'HALLORAN.

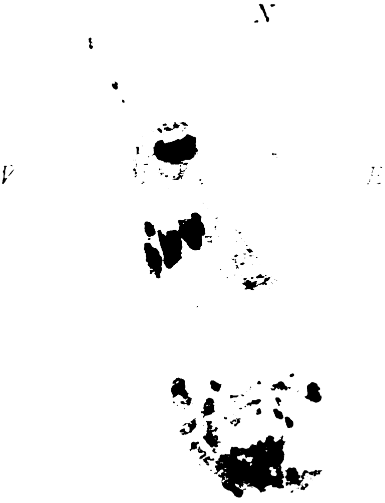
The recent sunspot cycle has been of unusual duration, though, according to data revised by Professor A. WOLFER, not beyond the limit of variations previously noted. Twelve and a half years elapsed between the extreme of the minimum, in the winter of 1890 and that of September, 1902, when it became evident to telescopic observers of the solar surface that a slow but steady increase of spottedness had commenced; while the incoming maximum of the summer of 1891 antedates by twelve and one quarter years the corresponding stage so conspicuous in October last. Not since September, 1898, has such an enormous formation discolored the white surface of the Sun.

In a four-inch telescope it was first visible on the morning of October 5th, while the easterly umbra was still in contact with the limb, and the branching penumbra was seen at parallel lines slanting in a northeast direction. A daily record of the condition of the solar surface shows that the tract was unspotted during the preceding rotation.



Large Sunspot, Oct 8, 1903, 9 A. M.
(Screen Image.)

On October 6th seven distinct umbræ were noticeable, which were increased to eleven on the day following, and on the 8th at least sixteen were strewn over the treelike penumbra. Having then emerged from the atmospheric haze of the solar limb, it was clearly visible without magnifying power, and when midway across the disk the main unbroken section measured about 130.000 miles. with an average width of 30.000. The central part extended in south heliographic latitude thirty-five degrees. its slow journey of nearly fourteen days from limb to limb also corresponding with this distance from the solar equator. Changes continued from day to day, and its largest midway phase, on October 11th, was altered in general outline, some nuclei having united, others having divided, while the encircling penumbra was more compact, though still mingled with clear photospheric areas. Then some mighty force gained sway in the region during the night, and when the 12th dawned the vast penumbra was rent crosswise in nearly equal parts. The intervening field of photospheric matter, about 30,000 miles in width was rhomboidal in form, with remarkably even angles, only one penumbral remnant, like an islet in a channel, surviving the swift symmetrical severance. As the formation advanced in the west quadrant, a decrease in the number of nuclei and a general decline were noticeable, but the wide rift was still apparent until the 16th, when the foremost section had disappeared at the west limb. On the 17th the remaining part was still distinctly seen, and about fifteen degrees in the rear was a new addition, a small faint spot, destined to be conspicuous in the succeeding rotation. On the morning following the large sections had passed from



Large Sunspot, Oct. 12, 1903, noon.
(Screen Image.)

view. In due time, twenty-seven days from its first appearance, a field of faculæ and a slight irregularity in the contour of the limb was discernible far to the south. This was on the 1st of November, 10:30 A.M. At noon the penumbra was visible, and at 4 P.M. the foremost umbra as a faint dark line. As the two sections advanced, they were seen to be much decreased in size and changed in form, but several degrees in the rear was a large scattered group, probably a development from the small spot above mentioned. When central in the southerly zones, this addition was about 70,000 miles in length, and made the group again visible to the unaided eye on clear days. Even more distinct was a conspicuous group with large umbræ in north latitude 15° that had appeared on the east limb on the 29th of October, while near the southwest limb was a rather large group that had come in on the 25th of the same month.

Though larger spots have been seen than any one of these three, the extent of spotted area at one time has not been equaled since 1894.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1904.

BY MALCOLM McNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon,	Jan.	2,	$9^h 47^m$ P.M.	Full Moon,	Feb.	1,	$8^h 33^m$ A.M.
Last Quarter,	"	9,	1 10 P.M.	Last Quarter,	"	8,	1 56 A.M.
New Moon,	"	17,	7 47 A.M.	New Moon,	"	16,	3 5 A.M.
First Quarter,	"	25,	12 41 P.M.	First Quarter,	"	24,	3 9 A.M.

The year 1904 is a leap-year, the first since 1896, and the regular succession of leap-years every fourth year will not be interrupted until the year 2100.

The Earth is in perihelion January 2d, 8 P.M., Pacific time.

Mercury is an evening star at the beginning of January, having reached its greatest east elongation, 19° 30′, just before midnight on December 31st. The elongation is not a very large one, as the planet passes perihelion only a few days later, on January 10th, but it remains above the horizon for an hour and a half after sunset on January 1st, and may be easily seen shortly after sunset under good weather conditions. It rapidly approaches the Sun, and can be seen as an evening star for only a few days. It reaches inferior conjunction on January 17th, and becomes a morning star, attaining greatest west elongation on the morning of February 10th. This elongation, 25° 52′, is much larger than the east elongation of January, as *Mercury* is nearly at aphelion; but as the planet is 5° south of the Sun the interval between the rising of the planet and of the Sun is about the same on February 1st, and continues to be as much as an hour until nearly February 20th. *Mercury* is in rather close conjunction with *Saturn* on the morning of February 26th, the former being 0° 49′ south of the latter at the time of nearest approach, 9 P.M., February 25th. They are both rather too near the Sun to be seen with the naked eye, except in especially fine weather.

Venus is a morning star, rising three and one half hours before sunrise on January 1st; but its more rapid eastward motion among the stars brings it nearer the Sun, and by the end of February it rises only about an hour and one half before sunrise. On the morning of January 11th it passes the first-magnitude star *Antares*, *α Scorpii*, about 7° north of the star. It passes less than 2° north of *Uranus* on January 28th; on the evening of February 12th it is 4° south of the Moon, and at the end of the month it is a little east of *Saturn*.

The year 1904 is a poor one for observations of *Mars*, as it is going through the part of its orbit which is farthest away from the Earth. However, its direction is still far enough away from that of the Sun so that it may be easily seen as an evening star. It does not set until about three hours after sunset on January 1st, and at the end of February a little less than two hours after. Its rapid eastward and northward motion among the stars has the rather unusual effect of making its time of setting almost exactly the same for the whole two months' period, the whole range being from 7:35 to 7:38 P.M., local mean time. It passes the vernal equinox about noon on February 20th, about 0° 40′ south. Also, on the evening of February 25th, it is in close conjunction with *Jupiter*, being about 0° 30′ north of the latter. This distance is about the apparent diameter of the Sun or Moon.

Jupiter is also an evening star, and is in comparatively good position for observation until March 1st. It does not set until well after 10 P.M. on January 1st, and at a little before 7:30 on February 29th. During the two-month period it moves about 11° eastward and 5° northward, passing the vernal equinox about 1° southward on February 28th. There will be a near approach to the Moon on the evening of February 18th. Its conjunction with *Mars* on February 25th has already been mentioned.

Saturn will be too near the Sun for easy observation during the greater part of the period. At the beginning it is still an evening star, setting about two hours after the Sun, but passes conjunction and becomes a morning star on February 1st. By the end of the month it rises about an hour before sunrise. It can then be seen with the naked eye if the weather is very clear; but it cannot be seen as near the Sun as *Jupiter* or *Venus,* as these are much brighter. Its conjunction with *Mercury* on the night of February 25-26th has been mentioned.

Uranus is a morning star, rising at about an hour before sunrise on January 1st, and at a little before 3 A.M. on February 29th. It is so faint that it cannot easily be seen until it is two hours or more above the horizon.

Neptune is an evening star, or rather it is both evening and morning star, having passed opposition with the Sun on December 27th, and being above the horizon nearly the entire night. It is in the western part of *Gemini.*

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

NEW DOUBLE STARS.

The continuation of my systematic search for new double stars has resulted in the discovery of about two hundred additional pairs, bringing the total number so far found up to about six hundred and thirty. The positions of all these new pairs, with detailed measures, will soon be published in the *Lick Observatory Bulletins.*

I wish here to call attention to only a few of them which seem to be of special interest. The positions are for 1900.0.

R. A., $2^h\ 54^m\ 46^s$; Decl., $-9^\circ\ 49'$.

A and B.

1903.80	309°.8	3″.64	8.1-13.5	3^n

A and C = h 3545.

1903.79	66°.8	43″.86	8.0- 9.0	1^n

The wide Herschel pair is of no interest as a double star; the new companion is too faint to measure with the 12-inch telescope.

R. A., $3^h\ 51^m\ 20^s$; Decl., $-7^\circ\ 14'$.

A and B.

1903.80	289°.1	0″.32	9.0- 9.2	3^n

AB and C = β 542.

1903.80	190°.6	1″.56	8.6- 9.5	3^n

The β pair shows no evidence of motion, BURNHAM'S measures with the 36-inch in 1892 giving 192°.5 and 1″.50. But if the new pair had been as easy at that time as it is now, it could not have escaped detection. The probability therefore is, that it is a binary in fairly rapid motion.

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* Lick Astronomical Department of the University of California.

R. A., $8^{h}\ 1^{m}\ 37^{s}$; Decl., —8° 57′.

B and C.

1903.82	324°.8	1″.17	8.5-12.0	1^{n}

A and B = Σ 1183.

1903.82	326°.8	30″.48	6.0- 8.5	1^{n}

The wide Struve pair is fixed. The new companion is not a difficult object, and should have been seen before, unless the distance has been less than at present. There are several other faint stars within 30″ of B.

R. A., $4^{h}\ 55^{m}\ 41^{s}$; Decl., +28° 9′.

1903.84	317°.3	0″.48	8.0-12.0	2^{n}

R. A., $4^{h}\ 59^{m}\ 24^{s}$; Decl., —6° 10′.

1903.83	357°.0	0″.24	7.0- 8.0	4^{n}

R. A., $5^{h}\ 38^{m}\ 2^{s}$; Decl., —6° 51′.

1903.80	121°.4	0″.14	6.9- 7.8	4^{n}

R. A., $21^{h}\ 16^{m}\ 29^{s}$; Decl., +9° 55′.

1903.84	272°.5	0″.18	7.0- 7.0	3^{n}

R. A., $21^{h}\ 50^{m}\ 32^{s}$; Decl., +43° 35′.

1903.68	247°.3	0″.20	8.0- 8.1	3^{n}

These five pairs well illustrate the efficiency of the large telescope for this class of work. Under good conditions the 36-inch shows them all so distinctly that good measures can be made without special difficulty. The first pair is the most difficult one, and it is doubtful whether it could be measured with a much smaller aperture. The fifth pair was noted as "double?" with the 12-inch. The fourth pair forms the 6.5-magnitude star 7^{m} following and 20′ north of δ *Equulei* and belongs, as do also the second and third pairs, to the class of double stars in which we expect to find rapid orbital motion.

That not all the new pairs are so difficult is shown by the following example, which would be an easy pair for a good six-inch telescope:—

R. A., $2^{h}\ 37^{m}\ 56^{s}$; Decl., —6° 55′.

1903.75	110°.8	1″.50	8.4- 8.5	3^{n}

November 12th, 1903.

R. G. AITKEN.

THE D. O. MILLS EXPEDITION TO CHILE.

The installation of the D. O. Mills Expedition to the Southern Hemisphere was no doubt completed in October. The observatory is erected on the summit of San Cristobal, in the northeast suburbs of Santiago. Its elevation above the city is about 950 feet, the altitude of Santiago above sea-level being 1,800 feet. The buildings, dome, reflecting telescope, spectroscope, etc., were in place early in September, and the latest mail advices stated that the electric line to supply current for maintaining the spectroscope at a constant temperature was under construction. The length of the line from the summit to the electric plant at the base of the hill is one kilometer.

The expedition reached Chile just at the breaking out of a series of labor troubles. This and the storms of winter made the construction of the observatory one of considerable difficulty. At the time of last writing, October 9th, Astronomer WRIGHT, in charge, reported that spectrograms had been secured for determining the velocities of twenty or more stars.

It is expected that a full account of the expedition, accompanied by illustrations of buildings and instruments, will be available for publication in the near future. W. W. C.

THE NEW VARIABLE, 59.1903 CYGNI.

The new variable in *Cygnus*, first announced by WOLF as a *nova*, and later identified as DM + 37°.3876 by BARNARD, was observed here with the 12-inch equatorial telescope for magnitude and position on October 5th. Comparison was made both with photometer and micrometer with the Lund A. G. star 9237 ($8^m.9$). Applying the necessary correction of — 1′ to the catalogued Declination of this star (announced by Professor H. A. HOWE, in *A. J.* 548), the resulting position is:—

α 1903.0, $20^h\ 14^m\ 57^s.01$ δ 1903.0, $+37°\ 08'\ 47''.5$

The magnitude observations were made with the wedge photometer designed by Professor E. C. PICKERING for the determination of faint stellar magnitudes. The wedge constant and the absorption of the shade-glasses have not yet been accurately determined. The provisional values used, however, are perhaps not more than ten per cent in error. Following are the observed magnitudes:—

	G. M. T.	
Oct.	$5^d.72$	$10^m.2$
	12 .84	10 .5
	16 .81	10 .8
	22 .75	10 .5
Nov.	6 .76	10 .6

Nov. 23, 1903. JAMES D. MADDRILL.

VISITOR TO THE LICK OBSERVATORY.

Professor C. MICHIE SMITH, Director of the Kodaikanal Observatory, India, visited Mt. Hamilton in November. The Kodaikanal Observatory has been under construction for several years past, and the equipment is nearing completion. It is located on the summit of one of the principal peaks in the Palani Hills, in the Madras Presidency, at an elevation of 7,700 feet. Director SMITH'S plans are to limit the work almost wholly to the study of the Sun.

Professor SMITH is also in charge of the Madras Observatory, now devoted largely to the meteorological and time services, the climate of Madras not being favorable for astronomical investigation. His visit to the Lick Observatory was a source of pleasure to all the members of the staff.

W. W. C.

GENERAL NOTES.

The Longitude of Honolulu.—Mr. John F. Hayford presented to the Philosophical Society of Washington on October 10, 1903, an account of the various determinations of the longitude of Honolulu that have been made since 1555. Assuming as correct the recent determination by the telegraphic method of the difference of longitude of San Francisco and Honolulu, which gives the position of the Transit of *Venus* pier at Honolulu as $10^h\ 31^m\ 27^s.24$ west of Greenwich, Mr. Hayford gives a table showing the errors of earlier determinations. It is very interesting to note that as early as 1785 Captain Cook determined the longitude within 18^s, or 4½ miles,—a high degree of accuracy when the poor construction of the chronometers of that day is taken into account,—while Captain Freycinet in 1819 obtained a result that differs only 1^s, or about one quarter of a mile, from the most recent determination. All the maps of the Hawaiian Government Survey since 1874 are based on the longitude determined by Captain Tupman from observations of meridional transits of the Moon, occultations of stars, and zenith-distances of the Moon's upper and lower limbs, combined with those of well-known stars near the Moon. This value is $10^h\ 31^m\ 27^s.2$, agreeing with the new determination to the nearest tenth of a second.

The Planet Mars.—Additional contributions to the extensive literature on the canals of *Mars* are made by Messrs. E. M. Antoniadi and E. W. Maunder in the November number of *Knowledge*. Instead of giving us new markings and canals, it is rather the object of these gentlemen to explain away some that now mark the maps of *Mars*. M. Antoniadi's conclusion seems to be that the so-called canals are not a simple phenomenon, either objective or subjective. It is his belief that these markings are, in part at least, real, but in greater part are due to physiological causes. In a letter to the *English Mechanic*, quoted by Mr. Maunder, M. Antoniadi sums up the 'canal-impression' under five heads:—

> "(*a*) Entirely physiological markings, like those seen by Mr. LOWELL on other planets, by myself on *Mars,* and by Mr. LANE on his artificial disks.
>
> "(*b*) Subjective lines, generated by the topographical details.
>
> "(*c*) Edges of physiological half-tones, begotten by contrast.
>
> "(*d*) Edges of objective half-tones, arising from the same reason; and
>
> "(*e*) Incontestably real canals, which, were we to see *Mars* better, would resolve themselves into groups of knotted or unevenly shaded areas."

Mr. MAUNDER describes in some detail, and with illustrations, the results of experiments made by him with a class of twenty boys, about twelve to fourteen years old, who were seated in four or five rows at different distances from a carefully lighted diagram, which they were told to copy. The diagram was reproduced from some published drawing of *Mars,* but in nearly every experiment the canals were omitted. In general, any boy was used in only one experiment, though a few drew the same diagram twice, at different distances.

> "The general result was striking. In several of these experiments nearly all the boys drew 'canals' on their copies, though there were none on the orginal from which they were copying. And these 'canals' were not placed at random; they were in just the very places where canals are seen in the charts of SCHIAPARELLI and LOWELL."

We cannot quote at greater length from this interesting article, but must refer our readers to the original. We may add that, as Mr. MAUNDER says, "the most interesting feature with regard to the entire discussion is the tendency of the ablest and most favorably circumstanced observers to see the chief canals no longer as straight uniform lines, but as close sequences of spots, as if an approach had been made to their complete resolution."

A stained-glass window, to commemorate the long connection of Dr. JOHN P. NICHOL, Professor of Astronomy, and his family with the University of Glasgow, has been placed in the Bute Hall of the college. At the top of the new window appears URANIA, the heavenly muse. In the smaller lights around her are various objects familiar to astronomers. The four figures in the top division of the window represent COPERNICUS, GALILEO, KEPLER, and NEWTON, the four great founders of modern astronomy. The late professor wrote numerous and delightful books on "The Solar System," "The Planetary System," and "The Architecture of the Heavens," and these works stimulated throughout the English-speaking world an extraordinary interest in the subject. ANDREW GRIEG.

Those who are interested in the question whether long-period weather forecasting will ever become practicable will find in *Science* for November 13, 1903, an interesting article by Sir NORMAN LOCKYER, entitled "Simultaneous Solar and Terrestrial Changes." The paper is really a concise historical account of the progress made in the study of such solar phenomena as the periodicity of the spots and the distribution of the prominences, and of the influence of such solar disturbances upon magnetic and meteorological conditions on the Earth.

From *Science* we learn that the new observatory of Amherst College has been so far completed that regular observations are in progress. The sum of $100,000 has been raised for building purposes and for endowment.

Another new observatory that is well equipped for research as well as for instruction is the Washburn College Observatory, Topeka, Kansas, which was dedicated on September 18, 1903, Professor C. L. DOOLITTLE, of the Flower Observatory, delivering the address. The equipment includes an 11½-inch refractor and a 5-inch photographic doublet, as well as a number of smaller instruments. It is designed to add other instruments (in particular, a meridian-circle and a spectroscopic outfit) and a working astronomical library.

Professor DOOLITTLE's address, just mentioned, is published in full in the November number of *Popular Astronomy*. It is entitled "Some Observatories and Observers, Past and Present," and gives an interesting account of the incidents and efforts that led to the establishment of some of the best-known observatories in Europe as well as of the development of astronomy in this country.

Autobiography of Professor SIMON NEWCOMB.—Under the title "The Reminiscences of an Astronomer," HOUGHTON, MIFFLIN & CO. have recently published an autobiography of the able and well-known astronomer, Professor SIMON NEWCOMB. This volume, modestly relating the chief events in the life of one who has been extremely influential in promoting American astronomy, makes very interesting reading. W. W. C.

PUBLICATIONS OF THE LICK OBSERVATORY, VOLUME VI.

Volume VI of the *Publications of the Lick Observatory* is a substantial book of 405 pages, containing the work of Professor Richard H. Tucker with the Repsold meridian-circle from August, 1896, to March, 1901. Four thousand five hundred stars have been observed, 11,700 complete observations of both Right Ascension and Declination having been made, and 2,700 other determinations of one of these coordinates only. That so large an amount of high-class work has been done by a single observer in a time so short is exceedingly creditable to the Lick Observatory and to the astronomer who made the observations.

There are six main divisions of the volume, and we shall review each separately.

THE DECLINATIONS OF THE BETHLEHEM LATITUDE STARS.

The most extensive series of observations for the determination of variation of latitude ever made in this country is that executed by Professor C. L. Doolittle at South Bethlehem, Pa. It is evidently a matter of importance that the declinations of Professor Doolittle's stars should be known with considerable accuracy, and should be reduced to some standard system. Professor Tucker's observations have been planned with a view of accomplishing this reduction by means of observations of the stars in conjunction with suitable fundamental stars.

The average number of fundamental stars observed each night was more than one fourth of the total number observed on that evening. The working list of stars used in the South Bethlehem observations originally contained 347 stars, and three were added afterwards; two of these were not observed. The general plan was to observe each star four times, the instrument being reversed for the second pair of observations. It was Professor Doolittle's original intention to use the system of Boss for all the stars. Professor Tucker has reduced every star to this system, and has compared with the system of Auwers.

There were 68 stars common to Boss's "Declination of Fixed Stars," and the *Berliner Jahrbuch*. By comparing the declinations of these Professor Tucker has derived the following formula:—

$$\text{Boss-B. J.} = -0''.10 + 0''.002\ \delta^\circ$$

A comparison of the two systems was also effected in another way. For each of 120 stars the Declination was observed. The result thus obtained was compared with that given by Boss, and also with that of the *Berliner Jahrbuch.* Thus resulted the following formula:—

$$\text{Boss-B. J.} = -0''.08 + 0''.001\ \delta^\circ$$

The agreement of these two formulas is striking, and shows the accuracy of the observations. It also appeared from this investigation that the probable error of a *B. J.* declination is ± 0″.24.

The conclusion reached as to the systematic errors of the observations is, that those due to flexure, bisection, and the difference U. C.–L. C. are practically negligible.

By discussing the probable error of an observed declination, the following results were reached:—

Probable-error observation,	± 0″.09,	mean of four.
Probable-error graduation,	± 0″.08,	two positions.
Probable-error fundamentals,	± 0″.08,	group of twelve.
Total probable error,	± 0″.15.	

These figures speak eloquently of the accuracy of the work.

From each observation of a fundamental star combined with the nadir-reading (taken three times each full night) a value of the latitude was obtained. After applying the corrections for variation of latitude computed from Chandler's elements, and combining the observations by pairs in such a way as to eliminate the division error of the nadir-reading, the following value of the normal latitude was reached:—

$$\phi_0 = 37^\circ\ 20'\ 25''.42\ (\pm\ 0''.03)$$

The star-places originally derived by Professor Doolittle were taken directly from Boss, or reduced to that system, or occasionally adopted from some other authorities. Professor Tucker finds that the probable error of one of these declinations is ± 0″.4. It is evident that wisely directed and accurate observation with a modern meridian-circle has given results superior to those obtained by a careful discussion of material previously obtainable.

ADDITIONAL STANDARD CLOSE CIRCUMPOLAR STARS.

These stars, twenty-one in number, all lie above 82° of North Declination, and half of them are above 85°. They were observed at the request of Dr. AUWERS. The mean places for each year of the interval 1895-1905 have been published in *A. N.* 3440. If ephemerides giving the apparent places of these stars could be issued from year to year, or to cover periods of five years, they would be very useful to all observers who have occasion to make determinations of azimuth. As their magnitudes range from 5¼ to 7½, they could be handled even with the comparatively small instruments used in the field.

Each star was observed sixteen times, eight times at each culmination, half the time with the fixed circle east, and half the time with the instrument reversed. The ten close circumpolars which already form a part of AUWER'S A. G. C. system were employed in obtaining the constants of reduction; the clock-stars were chosen from a list selected by Dr. AUWERS; usually eight of the clock-stars were used each night.

Professor TUCKER gives a careful discussion of the possible errors affecting his observations, including those of the close circumpolars which were employed as fundamental; all of these quantities are fractions (generally small) of a second of arc. An important by-product of the investigation is, that the Poulkova refraction-tables do not accurately correspond to the meteorological conditions at Mt. Hamilton. The probable error of the final position of a star derived from sixteen observations is, in R. A., $\pm 0^s.005$ sec δ, and in Decl., $\pm 0''.08$. In this connection Professor TUCKER makes the following interesting statement: "As indicating how large a part the unavoidable errors in the reduction may play, the simultaneous observations of the transits of the two stars of the pair l_1 and l_2 of the list give an interesting illustration. Each star was observed completely, upon sixteen nights, and both transits are recorded. This gives thirty-two values of the mean difference at transit, $7^s.56$, with the probable error of one determination, $\pm 0^s.087$. The probable error of a transit is thus found to be $\pm 0^s.061$.

which reduces to ± $0^s.001$ sec δ, for the mean of thirty-two observations."

Such accuracy plainly shows the excellent quality of the "seeing," as well as the skill of the observer.

ZODIACAL STARS.

In the summer of 1898 the positions of half a hundred zodiacal stars were obtained by request of Sir DAVID GILL, for use in his heliometer measures of the major planets. In the first seven months of 1900 these stars were reobserved, and about an equal number added. For the earlier observations the places of the thirteen fundamental stars were furnished by Dr. GILL. By means of eight of these fundamental stars a comparison of Dr. GILL'S places with those of Dr. AUWERS was made. The mean difference in Right Ascension is $0^s.011$, and in Declination it is $0''.35$. In order to investigate the systematic error in Declination, Professor TUCKER compared the value of the latitude derived from the thirteen fundamental stars in Dr. GILL'S list with the value obtained by observing circumpolars. The two results differ $0''.56$; if only the eight stars given by AUWERS are used, and his declinations are adopted for them, this discrepancy is reduced to $0''.27$.

For the observations of 1900, fourteen fundamental stars were selected by Dr. GILL, but he published no places for them. The places of six of them were therefore taken from the *Berliner Jahrbuch,* and Dr. AUWERS'S corrections were applied to them. The eight stars which were not found in the *Jahrbuch* were specially observed, using AUWERS'S corrected *B. J.* stars as fundamental. Ten of the fourteen are found in NEWCOMB'S Fundamental Catalogue. The average difference between the coordinates adopted by Professor TUCKER and those given by NEWCOMB is $0^s.018$ in Right Ascension, and $0''.01$ in Declination. The probable errors of the places finally deduced for the zodiacal stars are for the annual results:—

$$\pm 0^s.011 \text{ in R. A.}$$
$$\text{and } \pm 0''.17 \text{ in Decl.}$$

Experiments with screens, to determine the correction to transits due to the magnitudes of the stars, gave the value of this as $-0^s.006$ per magnitude, faint stars being recorded later.

THE PIAZZI STARS.

All of the stars of Southern Declination found in **Piazzi's** Catalogue were given place in the working list, which thus embraced 3,088 stars. The observations were undertaken at the suggestion of Dr. H. S. **Davis**, who is engaged in a re-reduction of **Piazzi's** original observations. Two observations of each star were made, and several which were used as fundamental stars have naturally been observed a greater number of times. In all 7,600 observations (including circumpolars and nadirs) were made, on 146 nights. For 4,400 of the observations the circle-microscopes were read by Dr. R. T. **Crawford**. When he assisted in this manner, the average number of observations per night was sixty-one; when Professor **Tucker** was alone, the average number was forty-six.

The excellence of the meteorological conditions and of the construction of the observing-room is shown by the fact that ordinarily there is not a difference of one degree between the temperatures outside and inside the room when it is closed. Upon the best nights the temperature remains nearly constant, often changing less that a degree for several hours. The maximum change of barometric-reading during the four or five hours of an observing period was four hundredths of an inch. The care and skill of the observer are abundantly attested by the table of probable errors for those stars which were not fundamental. Since many of the observations were made at very low altitudes, where the images were poor, and the effects of irregular refraction much greater than the average, the observations were divided into five zones, each 10° in width. For stars between the equator and 30° south the probable error of the mean of two observations may be well represented by the expressions—

$$\pm 0^s.016 \sec \delta \text{ for R. A.}$$
$$\text{and } \pm 0''.23 \text{ for Decl.}$$

From 30° downward to 46°.8, which is the extreme southern limit in Declination, the error in Right Ascension increases a trifle, but that in Declination increases quite rapidly. Professor **Tucker** has derived the following approximate expression for the probable error in declination:—

$$\pm [0''.15 + 0''.09 (\tan \text{Z. D.} - 1)]^*$$

---

* The reviewer has taken the liberty of inserting the [ ], which do not appear in the original.

At the southern limit this expression reaches the value ± 1″.0, when the star is but 6° above the horizon.

The places used for the fundamental stars were determined by an extended discussion, for the details of which the reader must refer to the volume itself. The following direct quotations will give an idea of the problem by which Professor TUCKER was confronted and his solution of it:—

> "With the use of the Poulkova Refractions we should obtain the Latitude 37° 20′ 25″.39 from the Circumpolar stars observed at both culminations, during this series. The observations of Latitude from the *B. J.* Southern stars would indicate a mean correction of —0″.16 for its system of Declinations, down to —31°. The Latitude observations of the list of 303 would indicate a correction of —0″.56 for its Declination system down to —25°. Employing NEWCOMB's Declinations down to —31°, the indicated correction would be —0″.68. Employing the Declinations of BOSS, for the Standard stars —20° to —31°, the correction to his system would be —0″.72. Similarly for AUWERS's Southern Fundamental Catalogue, —20° to —31°, the correction would be —0″.92.
>
> "The evidence points strongly to a decrease in the Poulkova Refractions, for this place, if the standard systems above enumerated are to be reconciled with the observations made here. The differences increase proportionally, as Declinations, below the limits above, are used for the deviations of Latitude."
>
> "As explained in full detail, earlier, the observations have been reduced with such of the Southern Piazzi stars as Fundamental, as are included in AUWERS's corrected *B. J.* and 303, the system of the last-named having been adopted. In extending the Declinations beyond the limits of the Fundamental stars, comparisons with AUWERS, NEWCOMB, and BOSS have been made, for the determination of the corrections to the Poulkova Refractions, employed throughout."

The observations are grouped in two tabular exhibits. In the first there are given for each star the separate determinations of Right Ascension and Declination, and the correction to the latter derived by diminishing the Poulkova Refractions. The second exhibit is in the ordinary catalogue form, the refraction correction just mentioned having been applied to each Declination.

REFERENCE-STARS FOR *EROS*.

These observations were made to assist in determining the parallax of *Eros* at its opposition in 1900. There were 677 stars in all, which were observed on fifty-four nights, two determinations of the place of each star being made. The probable error of the final place of a star was ± 0″.20 in each coordinate.

MISCELLANEOUS OBSERVATIONS.

These embrace determinations of the places of forty-nine comparison-stars, for other observers or orbit-computers, of twenty proper-motion stars for Professor J. G. PORTER, of *Eros*, of *Nova Persei*, and of comets *b* 1897 and *c* 1898.

THE INSTRUMENTAL CONSTANTS.

Under this caption are given the values of the constants during the four years and a half covered by the observations in the volume. The twenty-eight determinations of the flexure correction vary from — 0″.31 to + 0″.21, the mean of all being only — 0″.045. The nadir-readings seem to depend a little upon variations of temperature. The changes of collimation are very small, and its average value is close to zero. The total range of the azimuth-error was $0^s.6$, and it varied somewhat irregularly. The level-error changed in general slowly and smoothly, having an average value of about $0^s.5$.

Professor TUCKER received assistance from time to time in reading the circle-microscopes, and in reducing the observations, from Messrs. AITKEN, CODDINGTON, CRAWFORD, CURTISS, DALL, PALMER, and STEBBINS, the work of each of whom is particularly described. It appears that, had he received no aid, he would have made and reduced about 2,500 observations a year.

One closes this volume of the *Lick Observatory Publications* with a high admiration for the energy, precision, and painstaking of the observer, and with a feeling of satisfaction that he uses an instrument so perfect in a location so favorable. The results speak for themselves, and are a distinct credit to American astronomy.

HERBERT A. HOWE.

CHAMBERLIN OBSERVATORY, DENVER, COLO., November, 1903.

Minutes of the Meeting of the Board of Directors, held in the Rooms of the Society, November 28, 1903, at 7:30 P. M.

President Von Geldern presided. A quorum was present. The minutes of the last meeting were approved.

The following members were duly elected:—

List of Members Elected November 28, 1903.

Mr. Sebastian Albrecht	Lick Observatory, Mt. Hamilton, Cal.
Miss Edith Allyne	N. W. Cor. Gough and Green Sts., S. F. Cal.
Dr. A. J. Atkins	494 and 496 Parrott Building, S. F., Cal.
Mr. Elwyn B. Gould	808 Juniper St., San Diego, Cal.
Dr. B. L. Newkirk	2218 Union St., Berkeley, Cal.
Dr. Harry East Miller	331 Pine St., S. F. Cal.
Mr. C. M. St. John	U. S. Custom House, S. F., Cal.
Dr. Omar A. Turney	U. S. G. S., Livingstone, Gila Co., Arizona.
Dr. W. Villiger	Jena, Germany.

The Librarian reported that the manuscript catalogue of the bound books in the Library has been completed, at a cost of $50, as authorized by the resolution adopted at the meeting of November 29, 1902. The report was adopted and filed.

It was, upon motion,

Resolved, That the next regular meeting of the Society (January 30, 1904) be held at the Students' Observatory of the University of California, at Berkeley.

Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific, held in the Lecture Hall of the California Academy of Sciences, November 28, 1903, at 8 o'clock, P. M.

The meeting was called to order by President Von Geldern. A quorum was present. The minutes of the last meeting were approved. The Secretary read the names of new members elected.

The following papers were presented:—

The Ring Nebula in *Lyra*, by Dr. B. L. Newkirk.
The Great Sunspot of October, 1903, by Miss R. O'Halloran.
Planetary Phenomena for January and February, 1904, by Prof. M. McNeill.

The Chairman then introduced the lecturer of the evening, Dr. B. L. Newkirk, who read his paper on the Ring Nebula in *Lyra*, and exhibited a number of slides of the principal nebulæ.

The meeting then adjourned.

OFFICERS OF THE SOCIETY.

Mr. OTTO VON GELDERN	*President*
Mr. S. D. TOWNLEY	*First Vice-President*
Mr. W. W. CAMPBELL	*Second Vice-President*
Mr. CHAS. S. CUSHING	*Third Vice-President*
Mr. R. G. AITKEN Mr. F. R. ZIEL	*Secretaries*
Mr. F. R. ZIEL	*Treasurer*

Board of Directors—Messrs AITKEN, BURCKHALTER, CAMPBELL, CUSHING, LEUSCHNER, MOLERA, CROCKER, VON GELDERN, PIERSON, TOWNLEY, ZIEL.

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Committee on Publication—Messrs. AITKEN, SCHLESINGER, TOWNLEY.

Library Committee—Mr. TOWNLEY (*Librarian*), Mr. RICHARDSON, Miss O'HALLORAN.

Committee on the Comet-Medal—Messrs. CAMPBELL (*ex-officio*), PIERSON, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FELIPE VALLE.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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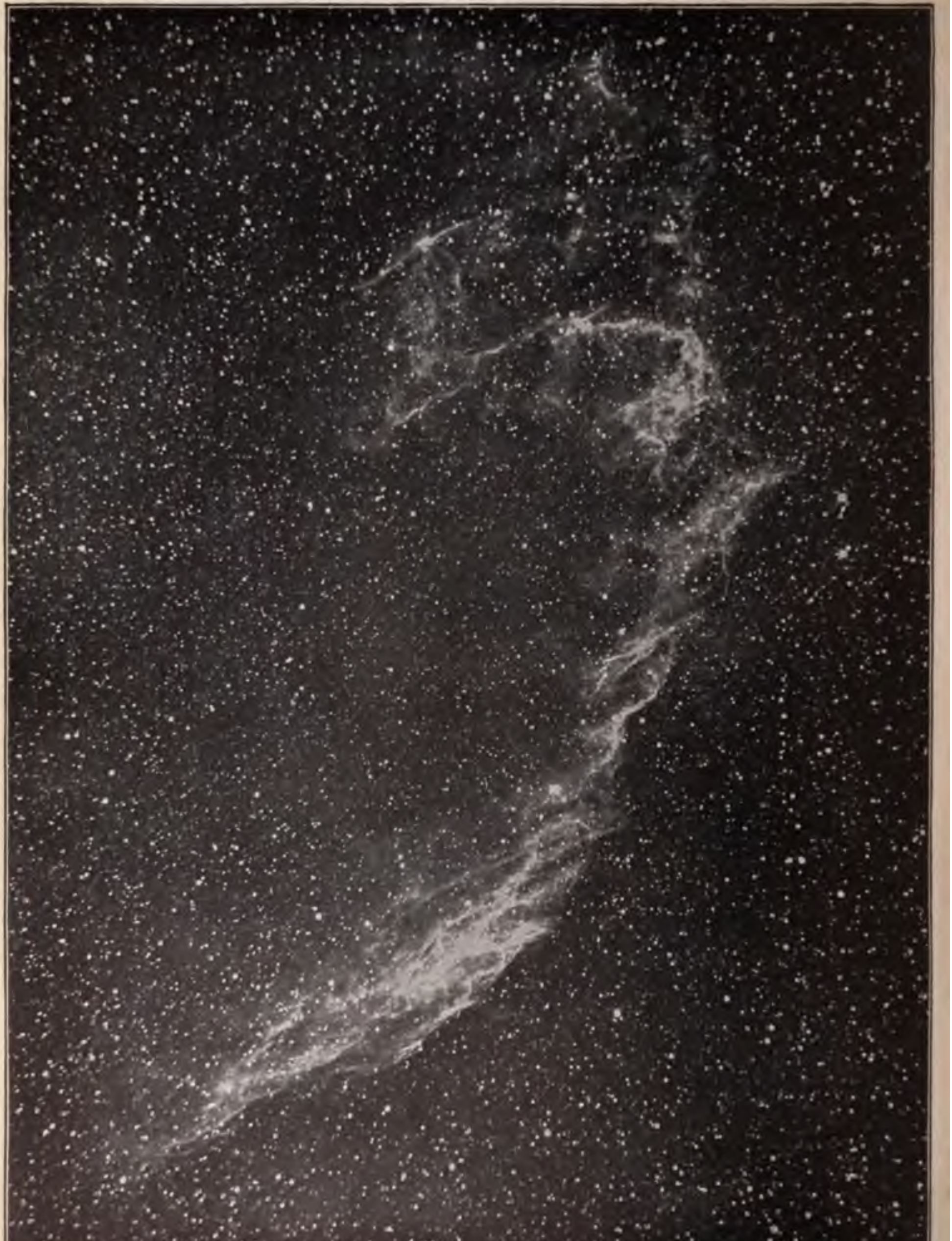

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Paris, France, Rue Cassini 16, Sociétè Astronomique de France.
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Washington, District of Columbia, The American Ephemeris.
Washington, District of Columbia, U. S. Coast and Geodetic Survey.
William's Bay, Wisconsin, Yerkes Observatory.
Zurich, Switzerland, Observatory.

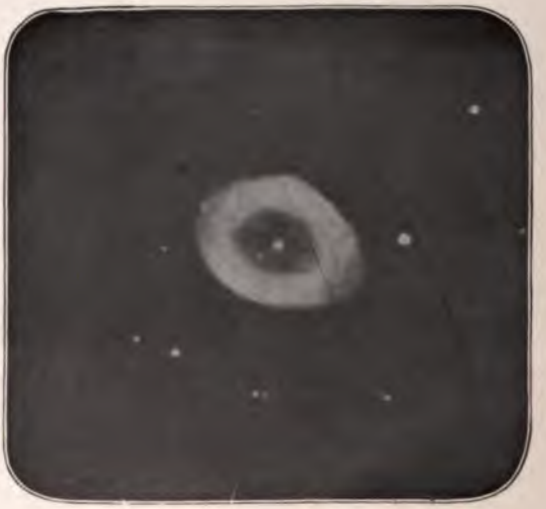
EXCHANGES.

Astrophysical Journal, William's Bay, Wisconsin.
Sirius, Cologne, Germany.
The Observatory, Greenwich, England.

FOR REVIEW.

[See *Publications*, A. S. P., vol. VIII, p. 101.]

The Call, San Francisco, California.
The Chronicle, San Francisco, California.
The Examiner, San Francisco, California.
The Mercury, San José, California.
The Record-Union, Sacramento, California.
The Times, Los Angeles, California.
The Tribune, Oakland, California.



RING NEBULA IN *LYRA* (MESSIER 51).

BY J. E. KEELER.

(By courtesy of the Editors of the ***Astrophysical Journal.***)

THE RING NEBULA IN *LYRA*.

By Burt L. Newkirk.

(Read before the Astronomical Society of the Pacific, November 28, 1903.)

Soon after sundown at this time of the year a bright bluish star may be seen in the northwest sky. It is the star *Vega*, the principal star of the constellation *Lyra*, and the brightest star of the northern hemisphere. The other stars of the constellation are inconspicuous. • Near one of the fainter of these stars is situated the Ring Nebula in *Lyra*, the largest and finest of the annular nebulæ. (See plate.)

The nebula as it appears in the photograph is oval in shape, somewhat broader and less intense at the ends, and contains a star in the center. A careful examination of the original negative shows that what appears here as a plain ring devoid of fine detail is really a composite structure showing interlaced streamers of nebulosity.* As seen in a telescope of ten inches aperture, the ring is large and bright, but the central star, which is so conspicuous in this photograph, and indeed in all photographs of the nebula, is visible to the eye only with the help of two or three of the largest telescopes in the world. Mr. Barnard says that it is a very difficult object with the great telescopes of the Lick or Yerkes observatories. The ease with which this star, so difficult to see, can be photographed is due to the fact that its light is composed largely of waves from the violet region of the spectrum, which affect the photographic plate more strongly than they affect the retina of the eye. A longer exposure than that given the plate from which this reproduction is made shows the ring to be entirely filled with faint nebulosity. Professor Schaeberle† has recently made some photographs of the nebula, from a study of which he concludes that it is really a spiral nebula, and that the ring-like appearance is due simply to the fact that the wisps of nebulosity which characterize the spiral are too faint and closely wound to be observed ordinarily. If this opinion of Professor Schaeberle's is confirmed, it will be an important contribution to the subject of nebular forms and the study of the typical life-history of nebulæ, as I shall show later.

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* Keeler, *Astroph. J.*, Vol. X, p. 193.

† Schaeberle, *A. J.*, Vol. XXIII, p 109 and 181.

Photography enjoys peculiar advantages in its application to the study of the structure of nebulæ, as compared with visual methods. It is safe to say that no eye has seen so much of the detailed structure of this nebula by direct visual observation as appears in the photograph of which this is a copy, taken with the Crossley reflector of the Lick Observatory by the late Director KEELER.

One who would gain a definite conception of the position this nebula occupies in the society of the heavens and its relation to the great plan of the universe must answer to himself the following questions: Where is it located? What are its physical characteristics and its composition? What has its life-history been, and what vicissitudes is it destined to undergo in ages to come?

First, where is it? How far is it from our Sun and his family of planets? Is its distance from us comparable to the distances of the stars, or is it immeasurably more remote, or is it perhaps a very near neighbor of ours? We shall see that it is in fact one of our celestial neighbors.

An investigation of the distance of a heavenly body is called a parallax determination. So far as I know, no nebula except this one has been made the subject of a successful parallax determination;* and of all the nebulæ of the skies the Ring Nebula in *Lyra* offers the most inviting opportunity to one wishing to determine a nebular parallax. It is the largest of the ring nebulæ, which fact gives countenance to the suspicion that it is nearer us than the average. The apparent size of a celestial object as seen from the Earth depends upon two things; its actual size and its distance from us. Since the Ring Nebula appears larger than other nebulæ of its class, it is then either actually larger than the other nebulæ or nearer to us than they are. Either alternative is, *a priori*, as probable as the other, and if the latter holds it would favor the choice of this nebula for a parallax determination, because the fact is that most celestial objects outside the Sun's system are so far away that their parallaxes are immeasurably small. Certainly not one star or nebula in a thousand has a parallax as large as a tenth of a second, and the usual result of a parallax investigation is simply to show that the object is so far away that its distance cannot be measured with the accuracy at present attainable. In choosing an object for a parallax investigation we ought therefore to fix upon one which we have reason to believe is nearer than the average if we hope for anything but a negative result. This is the only one of the nebulæ, with perhaps one exception, that has been found to show evidence of proper motion. Its proper motion tends to confirm the hypothesis of the proximity of the nebula. The relation between proper motion and parallax has been explained by Professor NEWCOMB* in a recent number of the *Astronomical Journal*. Moreover, the central star of this nebula offers a point of vantage for accurate micrometric measurement. This is a very great advantage, inasmuch as the indefinite and hazy character prevalent among nebulæ renders the refined measurements necessary for parallax determination practically impossible.

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* YOUNG'S *Manual of Astronomy*, 1902, §904

The investigation of the parallax of the central star of the Ring Nebula in *Lyra*, to which I have referred,† differs from other determinations of parallax only in the number of comparison-stars used, in the symmetry of their positions, and in a consequent simplification of the process of reduction of the measures, accompanied by a gain in accuracy. Instead of taking four to six such comparison-stars, as is generally done, sixteen were chosen. It was possible to measure sixteen distances on the photographic plate and carry through the reduction for the whole sixteen, with an increase of labor which was slight in comparison with the advantage gained in the precision of the result. The stars chosen were all faint and differing little in magnitude from the central star of the nebula. They were arranged in eight pairs, and the two stars of each pair were situated at about equal distances from the nebula star and in opposite directions. This symmetry of the position of the comparison-stars made possible the use of the short method of reduction mentioned above, making it unnecessary to apply special corrections for aberration or refraction, which effects a great saving of labor. Moreover, only three of the eight pairs of comparison-stars were chosen in the line of the major axis of the parallactic ellipse. There was a marked advantage in the diversity of the position-angles of the remaining pairs, as this made it possible to investigate certain possible sources of error. The result was a parallax of about one tenth of a second, with a probable error of about one eighth of that amount, and an annual proper motion of fifteen hundredths of a second. That is, the radius of the Earth's orbit, as seen from the star, subtends an angle of one tenth of a second, or this star is about thirty-three light-years distant. If this central star actually forms a part of the nebula, and is not, as some have suggested, a star far this side of or far beyond the nebula, which merely happens to be projected upon the nebula as we see it,—supposing, I say, that this star is a part of the nebula, then we may say that the *nebula* is about thirty-three light-years away from us; i. e., it would take light thirty-three years to come to us from the nebula, traveling at the rate of one hundred and eighty-six thousand miles per second. Inasmuch as the great majority of the stars and nebulæ are certainly hundreds, and even thousands, of light-years away, we are justified in regarding the Ring Nebula in *Lyra* as one of our nearest celestial neighbors.

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* *A. J.*, Vol. XXII, p. 165

† Dissertation, University of Munich, 1902 (B. L. NEWKIRK).

Knowing the distance of the nebula, and having the measures of its apparent dimensions as seen from the Earth, we can form an estimate of its actual size. Its longest diameter is about forty seconds,* which corresponds to an actual distance of four hundred times the radius of the Earth's orbit, or fourteen times the radius of *Neptune's* orbit. The smallest radius of the inside of the ring is fifteen seconds, corresponding to a distance equal to five times the radius of *Neptune's* orbit. Thus the whole of the solar system could be put into this ring and would have plenty of room to spare. I am speaking now, of course, of the ring of bright nebulosity shown in the picture. It has already been noted that longer exposures show the ring to be entirely filled with faint nebulosity.

It is to be presumed that the law of gravity holds there as it does in the solar system, and in that case the nebula may be in rotation about an axis coinciding with the axis of the ring, though this is not necessarily the case. This rotation would undoubtedly be very slow. How long it would take to accomplish a complete revolution cannot be stated without knowing the mass of the ring and of the central star, but we might surmise that something like three thousand years would be required.[*] It must not be supposed that the whole ring rotates as a rigid body. This could not be the case. The particles composing the ring move about with a good deal of freedom, each in its own orbit, with occasional collisions, much as do the discrete pieces composing *Saturn's* rings.

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* KEELER, *Astroph. J.*, Vol. X, p. 193.

The result of the determination of proper motion would lead us to believe that the Ring Nebula is moving along through space with a component of velocity perpendicular to the line of sight of about five miles per second, which is only about one fourth of the average stellar velocity.

It might be objected that this measurement of the distance does not apply to the nebula at all. It is not the nebula whose distance from the Sun's system has been measured, but the central star, and we have no conclusive evidence that the star belongs to the nebula. It might, as hinted at a moment ago, be some star a long distance from the nebula but in line with it as seen from the Earth, so that it only appears to be in the center of the nebula. In answer to this objection it can be urged that it would certainly be a very curious coincidence it this were the case. It would not be at all likely that a random star, having no connection with the nebula, would be so situated as to appear to us to be exactly in the center of the ring. I say it would be a curious coincidence if this were to occur in a single case, but much more so if it were to occur in a number of instances. There are other smaller nebulæ of the annular type, and most of these show faint stars in the center. Observers of experience[†] seem to think that all annular nebulæ have these central stars, only their faintness rendering them invisible in some instances. This alone is very convincing evidence in favor of the view that the central star of the Ring Nebula in *Lyra* is actually a part of the nebula. There is, however, corroborative evidence in the fact that an examination of the color of the central star shows it to be of a somewhat greenish tint, which color characterizes nebulæ rather than stars. Until very recently there was no instrument in existence with which the spectrum of this central star could be investigated with any degree of accuracy, and so, for want of a better method, Mr. BARNARD adopted the following program.* He carefully focused the forty-inch telescope of the Yerkes Observatory on different stars and took the readings of the focal micrometer in each case. He found that for white stars the readings were all about the same, but there was a marked difference in the reading of the focal micrometer when the telescope was focused upon a gaseous nebula. As light of different colors comes to a focus at different distances from the lens, this was a rough method of testing the color or spectral character of the object pointed at. Then Mr. BARNARD pointed at the central star of the Ring Nebula in *Lyra* and focused carefully. He obtained the following results from the readings of the focal micrometer (the results are given in fractions of an inch): Neb.-Nuc., + 0.20; Neb.-star, + 0.30; Nucleus-star, + 0.10. This shows that the light of the central star differs from the light of an ordinary white star in partaking somewhat of the nature of the light of the nebula. At the time of his death, Professor KEELER was planning to adapt the Crossley reflector to the spectroscopic study of very faint stars, and he had particularly in mind the central star of the Ring Nebula in *Lyra*. This work has been carried forward under the direction of Professor CAMPBELL, and some results recently published by Mr. PALMER of the Lick Observatory staff. Mr. PALMER† has found it possible to photograph the spectrum of the central star, which he finds to be continuous in that part of the spectrum where the bright lines of nebular light occur. This is not decisive evidence in favor of the claim that the central star is a part of the nebula but it does not militate against the theory, which indeed needs no more evidence in its favor than has already been adduced.

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[*] Period of a satellite revolving about a body of five times the Sun's mass at a distance twelve times the semimajor axis of *Neptune's* orbit.

[†] BURNHAM, *Lick Obs. Pub.*, Vol. II, p. 159.

The question as to the physical character and composition of the nebula next demands attention. It is a gaseous nebula. Its spectrum shows bright lines, indicating the presence of hydrogen and some other substance or substances not known to exist on the Earth or in the Sun or in any of the stars. This substance seems to be characteristic of gaseous nebulæ, and has therefore been called *nebulium*. The gas of which the nebula is composed is probably in a condition of great tenuity.

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* BARNARD, *Monthly Notices*, Vol. LX, p. [illegible] KEELER, *Ap. J.*, Vol. X, p. [illegible]

† *Astroph. J.*, Oct. [illegible], p. [illegible]

like the upper regions of our atmosphere. The cause of its luminosity is a mystery. It is in all probability not due to heat. The presumption is, that the temperature of the nebula is not far above the absolute zero of interstellar space. The upper regions of our atmosphere often become luminous through electrical discharges, and the light emitted by nebulæ may perhaps be produced in this way. Sir NORMAN LOCKYER* proposes to account for the luminosity of nebulæ upon the theory that they are composed of swarms of meteorites in an atmosphere of hydrogen, and that the meteorites collide frequently, striking fire. There are, however, grave objections to this theory, especially in its application to ring nebulæ.

In former times many people believed this nebula to be an immense galaxy of stars. Sir WILLIAM HERSCHEL, who was the first to study nebulæ extensively, propounded the theory that all nebulæ were clusters of stars very far removed from the solar system, looking like bright clouds in the sky, because his telescope was not powerful enough to enable him to see them as individual stars. Many of the seeming nebulæ which he observed in the early part of his life were found later, with the help of a larger and more powerful telescope, to be clusters of faint stars. Thus he concluded quite naturally that a telescope powerful enough would show all nebulæ to be star-clusters. Now, stars are suns like the source of our light and heat, and it was the most natural step in the world to the conclusion that our Sun is but one of a galaxy of stars which make up a nebula, and that all nebulæ are such collections of suns or stars. It is apparent to any close observer that the stars visible on a clear evening are more thickly crowded together in the neighborhood of the Milky Way, and it is generally believed that our Sun is but one of a galaxy forming an immense ring, or disk, of stars. If one were removed to an immense distance from this galaxy it might look somewhat as the Ring Nebula in *Lyra* looks to us now, but its spectrum would not be that of a tenuous gas; it would be continuous, because the majority of the stars composing the galaxy give continuous spectra. Thus the spectroscope has put an end to such speculation with regard to the Ring Nebula in *Lyra*. It is not a galaxy of stars, but a body of gas at low pressure. In after life HERSCHEL completely changed his views regarding the composition of nebulæ, thereby anticipating the results of modern spectroscopic investigation. He concluded that some of the more whitish of the nebulæ really were unresolved clusters of stars, but that many other nebulæ about which he detected a greenish tint were masses of gas, which the spectroscope has since shown them to be. The whitish nebulæ give continuous spectra, and Professor SCHEINER* has recently found that the continuous spectrum of the spiral nebula in *Andromeda* is crossed by absorption-lines as is the spectrum of sunlight. This does not prove that such nebulæ are really galaxies of stars, each of which is comparable to our Sun in magnitude, but it does not disprove it either, and Professor SCHEINER believes this to be the case. He thinks that the spiral nebulæ are all systems of stars, like the stars of our Milky Way. If this theory is correct, they must be hundreds of thousands of light-years distant from us.

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* Sir NORMAN LOCKYER, *Meteoritic Hypothesis*, MacMillan & Co., 1890.

It is the ringlike shape of this nebula which has brought it into prominence. Presuming that the law of the attraction of gravitation holds there just as it does in the solar system, how can the material composing the nebula assume this ringlike shape? Why does not the whole mass fall toward the center and form a great sphere or spheroid like the Earth or the Sun or one of the planets? It is not enough to assume, as we seemed to a moment ago, in speaking of the rotation of the ring, that this rotation will maintain its equilibrium. I mean to say that we cannot take it for granted that there is any velocity of rotation whatever which would maintain the equilibrium of the ring. The study of figures of equilibrium is one of the most difficult and at the same time the most interesting branches of theoretical astronomy. The problem is this: Given a mass of gas or liquid, each particle of which attracts each other particle, according to NEWTON'S law of gravitation, and the whole mass rotating, to find what shape it will assume. In particular, as applied to this case, could a mass of gas rotate with such a velocity that it would assume the shape of a ring? If so, then the ring is a figure of equilibrium. This problem has been discussed by mathematicians of note, among others LAPLACE, MAXWELL, and Madam KOWALEWSKI.

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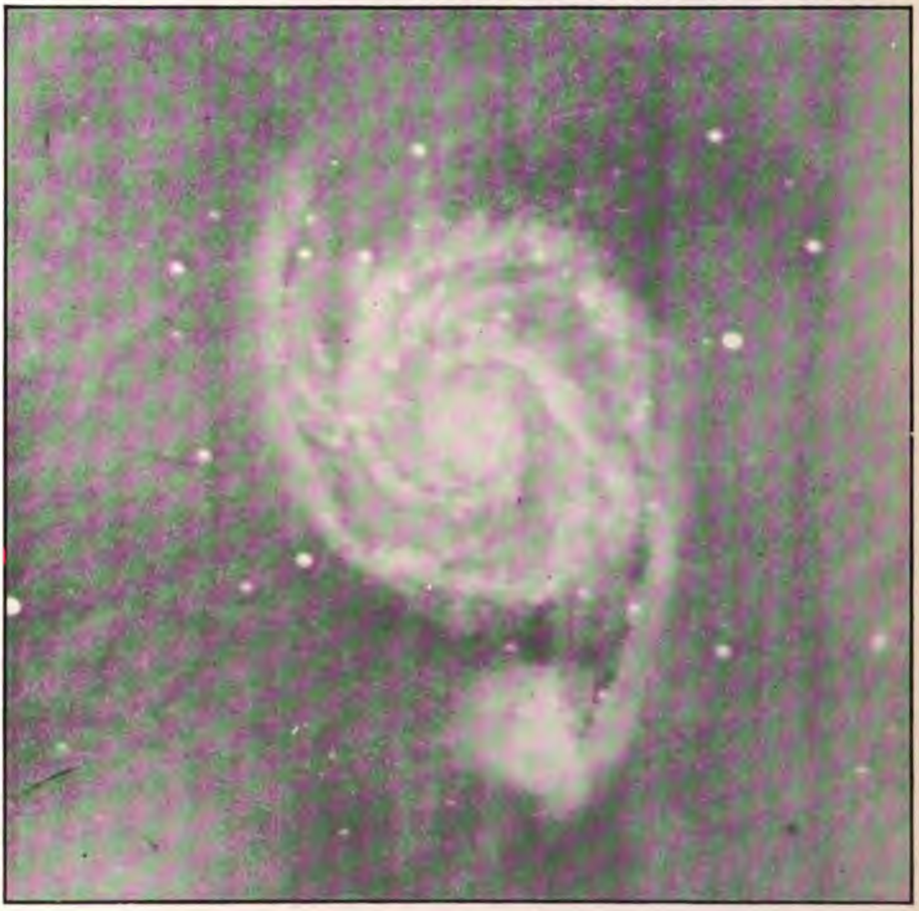
* SCHEINER, *Himmel und Erde*, Vol. XI, p. 325.



MESSIER 51 IN *CANES VENATICI.*

BY J. E. KEELER.

Madam KOWALEWSKI has answered the question in the affirmative. She has shown that a mass of rotating gas or fluid may take the shape of a ring and maintain this shape, unless disturbed by some external force. It is probable, however, that such a ring of gas could offer very little resistance to an external disturbing force; and as such forces certainly do exist and act upon the nebula, it is possible that in a comparatively short time it will gradually break down and assume some other shape, perhaps spherical. In a comparatively short time, I say; but this does not mean a few weeks or a few years, but rather a few hundred thousand or million years. Such processes go on very slowly, and it is hard to set an upper limit to the time that would be required to effect such a transformation.

Perhaps, however, the explanation of the ringlike appearance is to be looked for in an altogether different direction. Possibly the ring does not rotate at all, and in that case each particle swings like a pendulum from one side of the ring to the other, passing rapidly through the center and lingering at the extremities of the swing as a pendulum does. Thus at any given instant most of the material would be in the ring, since each particle spends most of its time at the extremities of its swing. If this is the case, the ring will be quite stable, and will gradually contract into a compact mass without breaking up.

Many investigations have been undertaken in times past in the hope of detecting changes in the shape or brightness of nebulæ, or the motion of the whole or any part of a nebula, but without marked success. Drawings of the same nebula made twenty or thirty years apart differ greatly, even when both drawings are made by the same man; but in almost every case these differences have been found to be due not to changes in the nebula, but rather to changes in the men who made the drawings and in the telescopes with which they worked. Nebulæ are in general very hazy and indefinite objects, exceedingly hard to draw correctly, and the same nebula often presents different aspects as viewed in different telescopes. It is not to be wondered at, then, that a comparison of old drawings of any one nebula should show much diversity, but no reliable evidence of any change in the nebula. Professor HOLDEN, formerly Director of the Lick Observatory, has made an exhaustive historical investigation of the Great Nebula in

Orion, and from the mass of evidence which he collects and examines he can only conclude that certain parts of the nebula have changed in brightness, but that no motion has occurred in any part of the nebula.

There is a new instrument which is destined to be very useful in the study of changes which occur in the celestial landscape. It has been recently designed, and is now being made in the Carl Zeiss optical workshop in Germany. It is called the stereo-comparator, and is in principle a carefully and accurately made stereoscope. In the ordinary hand stereoscope we have before us in the frame of the instrument a piece of cardboard upon which are mounted two pictures; and we look with one eye at the one and with the other eye at the other. The stereoscopic effect of depth in the picture is due to the fact that the two pictures before us are not made from exactly the same point of view. They are made simultaneously by two lenses mounted a few inches apart, and when we look at the two pictures in the stereoscope, one with the one eye and the other with the other eye, we get the same perspective effect as if we were looking with our two eyes at the scene of the picture. So sensitive are the eyes to this stereoscopic effect that a distance of a few inches between the lenses of the stereoscope camera suffices to give depth to the picture, making the nearer objects seem to stand out clear in front of those behind. This is the principle of the stereo-comparator. It is an accurately made stereoscope, enabling the observer to look with one eye upon one photographic plate and with the other eye upon the other. The eye detects very quickly slight differences between the two plates and thus a quick and easy comparison may be made of two accurate pictures taken years apart. It is in the study of nebulæ perhaps that this instrument is at its best. The flocculent, streamy, or cloudy detail of a nebula which only confuses one who attempts micrometric measures would be especially favorable to the detection of a stereoscopic effect due to proper motion or rotation of the nebula or change in its shape.

The question as to the past history of the Ring Nebula in *Lyra* and the prospects of its future career remain to be considered briefly. Was it always a ring nebula, and will it always retain the shape of a ring, or is this only a transitional form which has been recently assumed and will soon be abandoned? It is only by a comparative study of the observed forms of existing nebulæ that light can be gained on these points. Nebulæ present very diverse forms to our view. There are great diffuse nebulæ covering many square degrees of the sky and showing no definite outline; there are nebulæ of definite but very irregular shape; then there are spiral nebulæ, and ring nebulæ shading into planetary nebulæ by degrees so gradual that one is at a loss to draw a line of classification between the two. Diffuse nebulosity may be regarded as the earliest stage of nebular existence. The mutual attraction of the particles forming the nebula is very slight indeed, and contraction goes on very slowly. It is to be presumed, however, that these clouds are moving through space with velocities comparable with those of the stars: twenty or thirty miles per second. They are the winds of the heavens. The next stage is seen in such a nebula as Messier 8 in *Sagittarius,* which shows a tendency toward condensation. The form is irregular, and the mutual gravity of the particles forming the nebula is evidently not the predominant force. An attempt at condensation seems to have been frustrated, resulting in great irregularity of outline and the tearing asunder of the nebulous mass. The Trifid Nebula * is another case of the same sort. These dark lanes in the nebulosity are very curious. They are due perhaps to a collision of the nebulosity with a star, or rather to a star tearing through the nebula. One might at first imagine that the passage left by a star passing through a nebula would be closed up by particles of nebulosity rushing together in its wake, but this is not the case. It can be proven that the passage cleared by the star while passing through would not become narrower and gradually close up, but would get larger as time goes on. This process would not, however, continue indefinitely, because the attractive force exerted by the star while passing through, though powerful for the time being, is only temporary, and in the long run the effects of the temporary force would be obliterated by other weaker but ever-present forces. Thus it is to be expected that in the course of time these lanes will be closed up. The temporary and fortuitous forces are now in the ascendency, but in the long run the weak but ever-acting force of the mutual attraction of the particles forming the nebula will gain the ascendency and the mass will assume a more regular form.

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* See frontispiece to No. 74 of these *Publications.*

In the nebula in *Cygnus* the anarchistic forces seem to be triumphant. The nebula seems to have been struck by a celestial whirlwind and torn to shreds.

In the Great Nebula in *Orion* * we see evidence of a cataclysm befitting in its grandeur the magnificence of the stellar universe. Two nebulæ seem to have collided, and the débris of the conflict is scattered in the rear of the more powerful as it forces its way onward. The dark opening, somewhat resembling a fish's mouth, contains six stars, which are no doubt responsible for the disappearance of the nebulosity at this point. A dark lane such as we observed in the Trifid Nebula seems to be here in process of formation.

The spiral nebula, Messier 51 in *Canes Venatici*, shows the predominant action of the force due to the attraction of the central mass. One of the last, and perhaps the greatest, of the discoveries made by Professor KEELER was, that a large proportion of existing nebulæ have this spiral form.

Next in order comes the Ring Nebula in *Lyra*, and last planetary nebulæ.

We have traced the progression from the diffuse formless clouds of excessively faint nebulosity to the more dense irregular masses, and passed to the more regular spiral, ring, and planetary nebula. The slow process of contraction is not always left to take its course undisturbed, but it triumphs in the end.

The Ring Nebula may have been evolved from a spiral, or it may be a coördinate form, developed under more peaceful circumstances, where the force of the mutual attraction of the particles is not interfered with by disturbing influences from the outside. Perhaps the amount of rotational energy contained in the original mass is the deciding factor, slow rotation being favorable to the formation of a ring and rapid rotation favoring the spiral form. Professor SCHAEBERLE'S conclusion, that the Ring Nebula in *Lyra* is a closely-wound spiral, has an important bearing on this point. However this may be, it is certain that the ring form is one of transition which will some day give place to one more stable. In ages to come the material composing the Ring Nebula in *Lyra* will gather itself together into a central sun, accompanied perhaps by a family of planets, and thus become a mature member of the family of the universe.

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* See frontispiece to No. 66 of these *Publications*.

It was designed to have a series of seven plates to illustrate the nebulæ referred to by Dr. NEWKIRK, but to our regret circumstances beyond our control made this impossible.—THE EDITORS.

ASTRONOMICAL OBSERVATIONS IN 1903.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

VARIABLE STARS.

Z Cygni. *

Jan. 1: Z a little < a.
4: midway between a and b.
8: one step > b.
19: = a.
Feb. 1: = b.
< b.
> c.
20: id.
22: id.

Feb. 25: a little > c.
May 27: invisible.
Aug. 17: > d.
< c.
21: almost = c.
Sept. 12: = b.
23: = a.
29: id.
Oct. 20: a little > a.

S Ursæ majoris. †

Jan. 1: S midway between e and f.
4: two steps < e.
8: id.
13: one step < e.
19: id.
Feb. 1: > e.
< d.
15: id.
20: id.
22: = d.
25: one step > c.
March 1: one step > d.
22: > d.
< c.
24: id.

March 29: id.
Apr. 2: = d.
9: id.
14: id.
22: two steps < e.
May 27: = g.
Aug. 17: three steps < e.
21: id.
22: two steps < e.
Sept. 10: one step > e.
12: id.
19: one step < d.
23: id.
25: id.
29: id.
Oct. 18: = d.

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* *Vide* the sketch in the *Publications* A. S. P., No. 48, p. 69.

† *Vide* the sketch in the *Publications* A. S P., No. 73, p. 56.

T Ursæ majoris. *

Jan.	1:	three steps > a.	Apr.	2:	= f.
	4:	id.		14:	< g.
	8:	id.		22:	invisible.
	13:	id.	May	27:	id.
	19:	id.	Aug.	17:	one step > f.
Feb.	1:	= a.		21:	= e.
	15:	< a. > b.		22:	one step > e.
	20:	= b = c.	Sept.	10:	one step > b.
	22:	a little < c. b = c.		12:	id.
	25:	id.		19:	one step < a.
March	1:	< c. > d. b = c.		23:	= a.
	22:	two steps > e.		25:	id.
	24:	id.	Oct.	18:	id.
	29:	< e. > f.			

N. B.—Feb. 20–Mar. 1, inclu., was noted b = c; in the BD, b = 8.3 mag.; c = 8.5 mag.

Nova Persei.

		h.	m.			h.	m.
Jan.	1	9½ P.M.	9.2	Apr.	2	9 P.M.	9.6
	4	6	9.2		14	9½	10.0
	8	6½	9.2		22	9½	10.0
	19	7	9.4	Aug.	16	10	10.1
Feb.	1	8	9.6		21	9½	10.2
	15	8	9.6		22	9½	10.0
	20	8	9.3	Sept.	12	8½	10.2
	25	8	9.6		19	9	10.0
Mar.	1	9	9.6		23	9	10.0
	22	8	9.6		25	8	10.0
	29	9½	9.6	Oct	20	7½	10.0

In the last two months no observations could be made on account of change of abode and removing of the observatory to another place in the town.

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* *Vide* the sketch in the *Publications* A. S. P., No. 22, p. 63.

FIREBALLS.

In the past year twelve fireballs have been seen from stations in Denmark and surrounding countries, as follows: *

No.	Time.	Beginning.	End.	Mag.	Station.	Notes
1	Feb. 16, 6^{h} 38^{m} P. M.	352° + 49°	328° + 17°	♀	Odder.........	A beautiful fireball, turning pale, but suddenly growing up again to a great intensity. Duration, 12 seconds. Also seen in southern Norway.
2	28, 9 36	137° + 20°	195° + 38°	....	Odder, and several places in Denmark and Sweden.	The green meteor exploded twice, viz., in the positions 155° + 40°, and 180° + 42°. In Malmö (Sweden), where the meteor lighted up the whole region, an observer, who occasionally turned his back to the window, saw the image of the fireball in a polished brass lamp. At some places a loud detonation was heard, and the meteor apparently fell into the Baltic Sea. The flash was seen 300 kilometers away in all directions.
3	May 18, 9 30	......	NW.	....	Rinköbing, and several places in Denmark and Norway.	This meteor passed over the North Sea, and left behind a curious turning and winding train, which remained visible for twenty-five minutes.
4	Nov. 19, 6 45	W. SW.	E. SE. 70° altitude.	....	Kolding	The fireball was seen at several stations, where it lighted up the whole region, and consisted of two meteors, a large one and a little one following it.
5	19, 7 55	......	N. NE.	....	Haneke.........	Thin clouds covered the sky, when suddenly everything was lighted up from a shine behind the clouds; the meteor itself was not observed, but sixty seconds after its extinction a loud "thunder was heard from N NE.
6	19, 8 45	......	......	....	Sorö	A flash lighted up the whole region notwithstanding the misty weather This is the third large meteor on the same evening.

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* The details of the six most interesting of these meteors are here given.

A BRIEF ACCOUNT OF THE OBSERVATORY AT THAMES, N. Z.

(Long., $11^h\ 42^m\ 10^s.57$; Lat., S. $37°\ 8'\ 23.''21$.)

By J Grigg.

This observatory was erected in 1884, and contains a 3¼-inch refractor, by **Wray**, equatorially mounted, a 1¼-inch transit, by **Latimer Clark**, with mean-time and sidereal clocks; also a few subsidiary instruments.

The observations hitherto made include transits, eclipses, occultations, sun-spots, comets, and nebulæ. Photographic records were also made for a few years, but afterwards discontinued as regular work.

Since 1886, every comet visible has been observed, its path recorded, and its orbit investigated.

Since 1894, systematic search has been made for new comets, by sweeping the southwest sky, and the position of every nebulous object met with recorded.

In the latter part of 1894, Encke's comet being visible to northern observers, a search ephemeris was prepared for its southern path, by which it was found on February 24 and 25, 1895, its position agreeing very closely with that given in *Observatory*, No. 228, which came to hand two months later. So far as the writer knows, these were the only post-perihelion observations made. An ephemeris was afterwards prepared for searching for it on its return in 1898, by which it was found on June 16th, 18^h G. M. T. The information was posted to Sydney, and proved to be the earliest recorded by several days. This was afterwards acknowledged in the *Publications* of the Astronomical Society of the Pacific and the Royal Astronomical Society.

The only new comets hitherto discovered here have been 1902 *c* and 1903 *b*.

The observatory is not yet provided with charts and catalogues of the smaller telescopic stars; hence micrometric measurements can very rarely be made, as the tube of the telescope has to be shifted to the nearest known star for comparison; but it is estimated that, except near the horizon, the apparent position can generally be ascertained within about two minutes of arc.

November, 1903.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1904.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon,	March 1,	$6^h 48^m$ P.M.	Last Quarter,	April 7,	$9^h 53^m$ A.M.
Last Quarter,	" 8,	5 1 P.M.	New Moon,	" 15,	1 53 P.M.
New Moon,	" 16,	9 39 P.M.	First Quarter,	" 22,	8 55 P.M.
First Quarter,	" 24,	1 36 P.M.	Full Moon,	" 29,	2 36 P.M.
Full Moon,	" 31,	4 44 A.M.			

On the evening of March 22d the first-magnitude star *α Tauri* will be occulted by the Moon. The occultation will be visible from most parts of the United States, but the exact times vary so that the time for one place does not give much aid in estimating the times for other places. Another occultation of the same star will occur on April 18th, but it can probably not be seen from any part of the country except possibly the extreme west.

There will be an annular eclipse of the Sun on March 16th. The path of the annulus runs from eastern Africa, through the Indian Ocean, Siam, and ends in the Pacific. This is one of the two eclipses of the year. The other will come on September 9th, and will be total solar.

The Sun passes the vernal equinox and spring begins March 20, 5 P.M., Pacific time.

Mercury is a morning star at the beginning of March, but is too near the Sun for naked-eye observation, rising only about forty minutes before sunrise. It rapidly approaches the Sun, passing superior conjunction and becoming an evening star on the afternoon of March 26th. After that it rapidly increases its distance from the Sun until it reaches greatest east elongation, 20° 12′, on the afternoon of April 21st. It then remains above the horizon for an hour and three quarters after sunset, and may be easily seen in the evening twilight. At the end of April it sets about an hour and a half after sunset. The last two weeks in April give the best chance of the year for seeing the planet as an evening star. It passes only 5′ south of *Jupiter*, just five hours after passing conjunction with the Sun on March 26th. Unfortunately the proximity of the Sun prevents observation even with a telescope. ***Mercury*** is in conjunction with *Mars*, 1° 16′ north, on the afternoon of April 8th, and it is barely possible that the two planets may be seen near together on the evening of that day.

Venus is still a morning star, but is moving eastward faster than the Sun, and the two bodies are therefore apparently drawing nearer. On March 1st it rises an hour and one half before sunrise, but by the end of April the interval has diminished to about forty minutes. On account of the superior brightness of *Venus*, the planet can probably still be seen before sunrise, although none of the other planets, except possibly *Jupiter*, could be seen with the naked eye at this short distance from the Sun. It is in close conjunction with ***Saturn***, passing 0° 20′ north on the evening of March 7th, and with ***Jupiter*** on the morning of April 23d, passing 0° 30′ south.

Mars still remains an evening star, but toward the end of the two-months' period it is rather too near the Sun for naked-eye observation. On March 1st it sets about two hours after sunset, and at the end of April less than forty minutes after. As in January and February, the local mean time of setting remains nearly constant, $7^h\ 30^m$ P.M. on March 1st, $7^h\ 33^m$ on April 1st, and $7^h\ 26^m$ on May 1st.

Jupiter is also near the Sun. On March 1st it sets a little more than an hour and a half after the Sun; but the apparent distance between the bodies grows rapidly smaller, and the planet passes conjunction on the morning of March 27th. It then becomes a morning star, and is rapidly left behind by the Sun in their common eastward motion, so that by the end of April it rises about an hour and three quarters before sunrise.

Saturn is also a morning star, rising about an hour before sunrise on March 1st, and at the end of April at a little before 2 A.M. During this time it moves about 5° eastward and a little northward in the eastern part of the constellation *Capricorn*. As seen in the telescope, the rings appear less wide open than when the planet was seen as an evening star during the early winter, the ratio of minor to major axis being less than one fourth on April 30th. This shutting up of the rings has a material effect in diminishing the brightness of the planet.

Uranus continues to rise earlier, before 3 A.M. on March 1st, and before 11 P.M. on April 30th. It is in the western part of *Sagittarius,* and moves eastward until April 4th, and then moves westward, about half of one degree each way.

Neptune is in the western sky throughout the evening, setting at about 3 A.M. on March 1st, and at about 11 P.M. on April 30th. It is in *Gemini.*

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

THE LALANDE PRIZE AWARDED TO DIRECTOR CAMPBELL.

Comptes Rendus, 1903, December 21st, publishes the following report of Commissioners LOEWY, CALLANDREAU, WOLF, RADAU, JANSSEN, and DESLANDRES, of the Académie des Sciences in awarding to Professor W. W. CAMPBELL the Lalande Prize. This annual prize is awarded to the person who, in France or elsewhere, has "made the most interesting observation, or written the memoir or accomplished the work most useful to the progress of astronomy."

"The commission proposes unanimously to award the Lalande prize to M. CAMPBELL, of the Lick Observatory (California).

"M. CAMPBELL, connected for fifteen years with this observatory, first as astronomer, then as director, has made the best possible use of the great instrument and of the favorable situation of the observatory. Stellar spectroscopy and astrophysics have particularly attracted him, and in this new line of research, he has made important discoveries.

"He has taken up and followed the two principal lines of application of spectrum analysis to the stars, namely the investigation of their chemical composition and physical condition, and the investigation of their radial velocity.

"To him we owe the most thorough study of the numerous remarkable temporary stars of recent years; he has been able to follow to the last stages of their decline the most difficult for observation and to recognize their more or less complete transformation into nebulæ.

"He has also been largely occupied with the spectra of variable stars and of numerous stars exhibiting individual peculiarities; he has found a great number of stars which contain in their spectra both bright and dark lines from the same origin, and which thus form in a sense an entirely new type.

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* Lick Astronomical Department of the University of California.

"In the investigation of radial velocities his work is important. He has discovered about thirty spectroscopic binaries —a larger number than discovered by any other observer. One of these has such variations of radial velocity as to indicate two periods, and is therefore a triple system.

"In this time he directed one of the American expeditions sent to the Indies to observe the total solar eclipse of 1898. The results obtained regarding the spectrum and rotation of the solar corona are of the greatest interest.

"These many works assure M. CAMPBELL one of the first places among modern astronomers.

"The conclusions of this report are adopted by the Academy."

THE NEW YEAR'S TIME-SIGNALS FROM WASHINGTON, D. C.

The series of time-signals sent from the U. S. Naval Observatory throughout the United States at the beginning of the year created no little interest.

The standard clock of the observatory was connected by wire with the local telegraph-office and the beats of the clock were transmitted to all parts of the country. The electric connections of the clock are such as to omit certain seconds, enabling any one listening to a sounder to recognize the beginning of each minute and especially the first minute of the hour. The five seconds preceding the beginning of the minute are omitted, and for the beginning of the hour the ten seconds preceding are omitted. Hence the observer listening to the sounder is enabled to identify the hour, minute, and second of the Naval Observatory clock and compare it with his own.

The time-signals were received at this Observatory by telephone from the sounder in the Western Union office at San José at ten, eleven, and twelve o'clock, and a comparison made with the beats of a sounder electrically connected with our own standard clock. It so happened that the standard clock at this place was exactly correct at midnight, so that in making a comparison no correction was needed. At ten o'clock and eleven o'clock the comparisons were made by listening to both sounders—one through the telephone-receiver, the other in the telephone, both beside the observer. The sounders beat very nearly together, but it was thought that the Washington clock beat about $0^s.05$ after our own clock.

At twelve the two clocks were compared upon a chronograph—the observer in the telephone booth hearing only the beats of the Washington clock and recording them by breaking an electric circuit connected with the chronograph. The chronograph-sheet was read later, and for a series of twenty consecutive records showed the Washington clock to beat $+0^s.047$ later than our own.

It is proposed by the Naval Observatory to send out such signals each New Year, and no doubt, as people become familiar with the custom, a great deal of interest will be taken in the matter.

NOTE ON COMET BROOKS.

My observations of this interesting short-period comet from the date of its rediscovery, August 18, 1903, to October 24, 1903, are published in *Lick Observatory Bulletin*, No. 49. During this period the comet's brightness diminished rapidly, so that on the last date it was very difficult to make measures of it even with the great telescope.

Stormy weather and moonlight prevented further observations until December 10th, when it was found that a marked change had taken place in the comet's appearance. It was brighter than it had been when first observed in August, and had developed a nuclear condensation that was almost sharp enough to be called stellar. As the comet's distance from the Earth had meanwhile increased by nearly seventy millions of miles, this change must be credited to the internal activity of the comet, doubtless due to its passage through perihelion early in December.

An observation secured on January 15, 1904, shows that the comet will probably remain visible until March, if weather conditions are favorable.

R. G. AITKEN.

January 19, 1904.

GENERAL NOTES.

The *Astronomical Journal,* No. 551, contains an article by PAUL S. YENDELL, on "The Light Variations of 320 *U Cephei.*" The variability of this star, of the *Algol* type, was announced by CERASKI in 1880, and as there were but five stars of this interesting class of variables known at that time, the announcement attracted considerable attention.

Mr. YENDELL has collected all the observations of this star, —over three thousand altogether,—and has made a very careful discussion of them to determine the form of the light-curve. The magnitudes of the comparison-stars were determined photometrically by Dr. MÜLLER, of Potsdam; and CHANDLER'S elements, which were found to represent the observations very closely, were used in the discussion. As an indication of the care with which the investigation has been made and of the refinement obtained in variable-star observations, it might be noted that it was necessary to discuss separately the observations made in the spring and those made in the autumn. A small but appreciable difference is found in the resulting curves, the difference being, in all probability, a subjective rather than a real one, caused by the different relative positions of variable and comparison-stars in east and west hour-angles. It is to be regretted that no photometric observations of this star have been made, because with a properly arranged photometer this subjective effect can be entirely eliminated. It is to be regretted, also, that Mr. YENDELL has not published graphical representations of the curves derived. These help the reader immensely in properly grasping the results of the investigation. Regret number three may be in order at this point. YENDELL'S results have been obtained from discussion of the observations of eight persons,—BAXENDELL, senior and junior, CHANDLER, KNOTT, PLASSMANN, SCHWAB, SPERRA, and YENDELL. Only one of the series of observations made by these persons, KNOTT'S, and a part of PLASSMANN'S, have been published. All of the other observations, fully two thirds of the whole, were transmitted to Mr. YENDELL in manuscript. And so it is, if any one wishes to make an exhaustive study of the light-variations of any variable, it is necessary to send letters all over the world and ask variable-star observers to transmit their observations. This they are usually very glad to do, but it is easily seen that it would be much better for both observer and computer if the variable-star observations could be published. It is respectfully suggested that this might be an appropriate matter for the trustees of the Carnegie Institution to take under consideration. S. D. T.

The *Astronomical Journal,* No. 553, contains the results of some important investigations by Dr. CHANDLER, being a revision of the elements of his third catalogue of variable stars, published in 1896. All observations ***published*** since that time have been used in determining the revised elements. An important feature of the tabulation published is contained in the last three columns, which give the number of maxima and the number of minimi that have been used in deriving the revised elements, together with the limiting dates between which the observations were made. The observer can see at a glance which stars are in most need of observation. S. D. T.

The Memoirs of the British Astronomical Association, Volume XI, Part IV, contain the fifth report of the section for the observation of variable stars. The observations were made by about twenty members of the Association, under the direction of Col. E. E. MARWICK, and the present report covers the work done in the three years 1900-1902. The instruments used vary in size from one to twelve inches, the larger instruments being reflectors. The programme included the observation of four variables of the *Algol* type, nine short-period, twenty-five long-period, and eight irregular ones, and a total of 7,450 observations were made. These observations have all been reduced, and the resulting light-curves graphically represented in the memoir, a feature to be highly commended. S. D. T.

In *Monthly Notices of the Royal Astronomical Society,* Volume LXIII, No. 9, there is an important article by Professor WADSWORTH, Director of the Allegheny Observatory, on "The Construction of Telescopes Whose Relative or Absolute Focal Length Shall Be Invariable at All Temperatures." Two chief factors are to be reckoned with in this investigation, —the change in the focal length of the lens combination, and the change in the length of the telescope tube, and, for practical purposes, the problem will be solved if these two parts of the telescope be constructed of such materials that the change in the one is just compensated by the change in the other. There are three variables at the disposal of the investigator, the density of the crown glass, the density of the flint glass, and the material of the telescope tube. Professor WADSWORTH's attention was first called to this subject by the peculiar behavior of the new steel-tube meridian-circle of the Naval Observatory. While using this new instrument Professor UPDEGRAFF found an unmistakable change in its apparent focal length with changes of temperature; and it now appears that the amount of the change agrees very closely with that deduced by Professor WADSWORTH from the theoretical considerations. It appears, from the investigation, that for the lenses usually used for meridian-circles a brass tube gives almost perfect compensation, but a steel tube does not. It is possible, however, to so vary the glass of the lenses that compensation may be obtained with a steel tube.

It is possible to bring another variable into the investigation, and thus increase the exactness of the compensation, by constructing the telescope-tube of two parts of different materials. This may not be desirable for meridian-circles, but probably not objectionable for equatorials. Professor WADSWORTH suggests one combination of steel and nickel steel.

This subject of changes in focal length is of great importance in all meridian-circle, heliometer, photographic, micrometric, and spectrographic work, and designers of instruments will do well to take heed of the results obtained by Professor WADSWORTH. S. D. T.

The leading article in the *Astrophysical Journal* for October is one by Dr. HARTMANN, entitled "A Revision of Rowland's System of Wave-Lengths." By way of introduction, Dr. HARTMANN says: "ROWLAND'S system of wave-lengths has become the basis of all spectroscopic measurements made in recent years, and with the progressive increase in the precision of these measures the necessity has now arisen of testing the reliability of that important basis, and, in case it should not appear as adequate, of correcting it by new series of observations, in order thus to create a foundation sufficient for all demands."

Dr. HARTMANN then goes on to explain the methods used by ROWLAND in determining the wave-lengths of the various tables published by him, concluding that ROWLAND's "Preliminary Table of Solar Spectrum Wave-Lengths" is the most accurate. Even this table, however, according to HARTMANN's investigation, has a small systematic error running through it, but he thinks it is now possible to determine the necessary corrections to ROWLAND's wave-lengths. Special and delicate apparatus will be required for carrying out this work, and HARTMANN suggests that it would be advisable to have these researches carried out independently at a number of places.

S. D. T.

Sir WILLIAM RAMSAY, F. R. S., addressed the British Astronomical Association in London recently on "Some Speculations Regarding Stars and Atoms." In 1878 the French astronomer JANSSEN, and Sir NORMAN LOCKYER, in England, discovered a line in the Sun's spectrum near that which marks the presence of sodium, and, as it was then supposed to indicate an element peculiar to the Sun and unknown on Earth, it was called helium. Sir WILLIAM, by careful search, detected this supposed unknown element in the mineral clevite. The discovery came most opportunely, for it followed the finding of argon in the atmosphere, and helium belongs to the same class as argon, in being an inert body incapable of forming combinations with others. Since then other similar elements—neon, krypton, xenon—have been identified in the air, and they are of the same inert class. But these elements, especially helium and krypton, seem to afford an alluring link connecting terrestrial physics and chemistry with those of the Sun and stars. One of the speculations on which Sir WILLIAM ventured was, that the action of krypton may explain that hitherto obscure phenomenon, the aurora borealis. There is now reason to believe, as one outcome of the examination of radio-active bodies, that the Sun not only sends out rays of light and heat, but is also continually projecting into space corpuscles of electrified matter which electrify the regions of the upper atmosphere. It has long been thought that the aurora was an electrical phenomenon. Its radiant arch and brilliant streamers give this impression naturally. The problem was to identify the constituent of the atmosphere which was the subject of the electrifying action. Professor RAMSAY believes that he has discovered that constituent in krypton. In the ocean of air above us a ceaseless circulation is going on between the tropics and the polar regions, the heated air of the equatorial zone flowing northward at a great elevation, while the polar currents return at a lower level to the tropics. There is cause for thinking that krypton, though a heavy gas, ascends to the higher regions, because the element, being monatomic, would be more powerfully affected by tropical heat than elements like hydrogen and oxygen, made up of molecules of two atoms. And in those upper regions of the air we can suppose that it is electrified by solar corpuscles, and, becoming denser in the polar circle, gives out the aurora discharge. More than this, Sir WILLIAM showed that in a laboratory experiment with air in a globe containing krypton an auroral light can be produced. Moreover, the spectrum of the aurora and of krypton appear to be identical. Having described the discovery by BECQUEREL of the principle of radio-activity, and the isolation by Madame CURIE of the most wonderful example of that principle with radium, Sir W. RAMSAY explained the three species of radiations from radium,—the *alpha* rays, which are easily stopped; the *beta* rays, which are more penetrating (these two being material corpuscles charged with electricity); and the *gamma* rays, which will go through several inches of lead, and are undulations of ether resembling those of light or electricity. Besides these was the emanation of a heavy gas leaving a residuum, which he and Mr. SODDY had proved to be helium. Professor J. J. THOMSON had made it probable that the corpuscles given off by atoms were electrons, the *alpha* rays being positively and the *beta* negatively electrified; and they could conceive of an atom as a system in which a large number of small bodies might be revolving round a center.

Dr. JOHNSTONE STONEY had pointed out that there was probably a natural limit to the size of the suns and stars. When a sun exceeded a certain volume a portion of its mass would be thrown off. So it might be with the atom. In uranium and radium they had the heaviest known elements, and these, passing the natural limit of atomic dimensions, might be throwing off the electrons which in the case of radium produced such marvelous effects.—*Extract from the Scotsman.*

Harnessing the Dog Star.—A French astronomer, M. TOUCHET, who has previously photographed objects by the light of *Venus* and *Jupiter,* has now succeeded in obtaining a photograph by the light of *Sirius,* the most brilliant of all the stars. An ordinary camera was used, but the customary objective was replaced by a cardboard tube, to the end of which a small brooch, the object it was intended to photograph, was affixed. The light of the star was concentrated upon the brooch through a powerful lens, and the exposure lasted an hour and five minutes. The result was an admirable photograph of the star with a clear reproduction of the brooch in its center. When it is remembered, says the *Debats,* that *Sirius* is ninety-two trillion of kilometers from the Earth,. and that its light takes nine years and nine months to reach us, the rays which permitted the photograph to be taken must have been traveling through space since 1894 at the tremendous rate of 187,500 miles per second.—*Dalziel, London Daily Graphic, Dec. 5, 1903.*

A Royal Medal of the Royal Society has been awarded to Sir DAVID GILL, K. C. B., F. R. S., for his researches in solar and stellar parallax, and his energetic direction of the Royal Observatory at the Cape of Good Hope.

It is reported that among the subjects now under consideration by the Carnegie Institution in connection with grants are a solar observatory, a southern observatory, a geophysical observatory, and the establishment of international magnetic researches.

Transit-room shutters of a new design by Professor D. P. TODD were erected the last week in November at Amherst College Observatory. They were built by the Coburn Trolley Track Company and the Norton Iron Works, with special reference to ease and rapidity of working.—*Science, Dec. 18, 1903.*

Our amateur astronomers may be interested in the brief description, in the January number of *Popular Astronomy,* of a fourteen-foot dome built by one of our members, Mr. C. F. HARMS, of Brooklyn, N. Y. It is a good solution of the problem to attach to a residence, at a reasonable cost, a dome answering all reasonable demands.

Mr. ANDREW GRIEG sends us the following interesting extract from the *Scotsman:* "In a recent lecture on 'Other Worlds than Our Own,' Sir ROBERT BALL said we were most interested in our next-door neighbors, *Venus* and *Mars.* With regard to *Venus,* the Professor accepts as proved the theory on which Mr. WALLACE relies, that it always turns the same face to the Sun, so that one hemisphere has perpetual night, and the other unending day. He did not think that *Venus* was now the habitation of rational beings. Life there might be, but scarcely that of sentient beings like ourselves. Looking at the scores of millions of years of this world's existence, and the fact that 100,000 years would be a liberal estimate for human history, it seemed scarcely likely that rational life on *Venus* would be simultaneous with that here.

" For various reasons Sir ROBERT was inclined to think that no other planet of the solar system is likely to be inhabited at present by creatures like ourselves. In some the time is past; in others it may be yet to come. In time past the Moon may have been inhabited, but no distinct trace of atmosphere is now found, and its seas seem to have sunk into the cavernous interior, as most probably some day the Earth's seas will do.

" Professor BALL dismisses the canals of *Mars* as optical illusions, and is disposed to believe that we see few if any seas on its surface, but rather certain areas capable of supporting vegetation, and others desert. The pictures of *Jupiter* seemed to suggest that the planet was still too hot to be peopled—not through the Sun's heat, for that was only one twentieth of what we received—but in consequence of *Jupiter's* own high temperature as a cooling globe. What water exists is most likely not on the planet's surface. but is carried as vapor in its vast atmosphere. A succession of lime-light pictures was thrown on the screen to emphasize the transcendent grandeur of the stellar universe. and the countless number of worlds which it must contain. We see only the suns and bright nebulæ, but the dark unseen worlds were almost certainly many times more numerous. While rejecting the idea of an infinite universe with an infinite number of suns,—because then the firmament would be a blaze of light,—he enforced the thought that the whole of this group of worlds had a greater design than merely to teach man his insignificance, and that it was reasonable to suppose as there were suns vastly greater than ours, so there were many 'other worlds than ours,' some of them inhabited by beings of far greater capacities."

THE MOON: A SUMMARY OF THE EXISTING KNOWLEDGE OF OUR SATELLITE. With a complete Photographic Atlas. By WILLIAM H. PICKERING, of Harvard College Observatory. One hundred illustrations. New York: Doubleday, Page & Company, 1903. Price, special net, $10.00.

Although the title as given above states that this volume is a summary of the existing knowledge of our satellite, the author in the first sentence of his preface says, "It is intended in the present volume to give an account of some of the more recent advances in our knowledge of the Moon, leaving to the text-books a statement of the information that was earlier acquired." In point of fact the volume is chiefly devoted to the results of Professor PICKERING'S personal selenographical studies, particularly those made in Jamaica in 1901, touching upon other matters in the earlier chapters only so far as necessary to a better understanding of those observations.

One chapter, however, headed "Fancies; Apparent Size; Superstitions; Influence on the Weather," is added that has no particular bearing on the subject-matter of the rest of the volume, and is apparently introduced to make the work more "popular."

It is impossible at the present time to review this work critically. Such a task may more properly be undertaken by one who has made a specialty of selenography. It is my purpose merely to give a very brief account of the author's views, which in some respects are unusual and not as yet accepted by astronomers generally as fully substantiated.

The first point to attract attention is the claim made that any station situated near the equator possesses superior atmospheric conditions for astronomical work. Reading the preface, one would gather that nearness to the equator was the necessary and sufficient condition for a "steady" atmosphere, whether the station be located on an island or high up among lofty mountains. From such a location the author claims that a twelve-inch telescope will show planetary details invisible in the largest telescopes of this country and Europe. "What is now needed," he adds, "is a large telescope located near the equator, but just how near it is necessary or desirable to go has not as yet been definitely determined."

Passing on to the text, we find that the opening chapters treat of "The Moon's Origin; Its Relation, Distance, Orbit," etc. Then follow chapters on its Atmosphere and Temperature; the Origin of Lunar Craters, with an account of some miniature craters formed experimentally; Active Lunar Craters; Ice on the Moon; Vegetation and the Lunar Canals; and Recent Investigations. These chapters deal principally with Professor PICKERING's own observations, and the theories he has framed to interpret them. Then comes the chapter on "Fancies," etc., already mentioned, which in turn is followed by an account of the formation and arrangement of the photographic atlas of eighty plates, which, with a good guide-map, concludes the volume.

We find that Professor PICKERING agrees with astronomers generally in believing that the density of the Moon's atmosphere "does not exceed the one ten-thousandth part of our own." But he thinks that we have positive evidence that a very tenuous atmosphere does exist on the Moon and that it is "a factor in selenography by no means negligible." Since he agrees with other investigators in thinking that our ordinary atmospheric gases—oxygen, nitrogen, and in fact all gases, except perhaps the very heavy ones, like carbonic acid—would probably have escaped from the surface of the Moon long ere this, he finds the source of the present lunar atmosphere in gases "constantly renewed from the Moon's interior." "Let us now see," he proceeds, "what gases are at the present time being given off from the Earth's interior. We find that there are only two that escape in large quantities—carbonic acid and water-vapor. The former would remain for some time on the Moon's surface on account of its weight, and the latter because on account of the low pressure the rapid evaporation would cause it immediately to freeze."

Here we have at once the origin of the Moon's atmosphere, and of the "snow," or "hoar-frost," of which a great deal is said in the later chapters.

The discussion of the origin of the lunar craters and the account of miniature craters observed in cooling slag-iron, and others artificially formed from cooling paraffin, are very interesting, and will leave little doubt in the minds of most readers that the source of the lunar craters was volcanic activity.

The following chapters are devoted to the discussion of gradual changes that various observers have noted in such craters as *Linné* and *Plato,* and many changes, observed by Professor Pickering himself, which differ from those noticed earlier, in being periodic, the periods depending on the alternation of the lunar night and day. The explanation of most of these periodic changes the author finds in the exuding of water-vapor from crevices in the Moon's surface, its freezing during the lunar night and its consequent deposit in the neighborhood of the crevices as "hoar-frost," and its more or less complete evaporation during the lunar day. The author presents detailed evidence, illustrated by drawings and photographs, in favor of the reality of these periodic changes and of the adequacy of his theory as to their cause. As was said in the beginning, it is not our purpose to discuss this evidence here; nor can we examine critically the arguments advanced in favor of the theory that certain "variable spots" that Professor Pickering sees upon the Moon are due to the coming up, flourishing, and dying of low forms of organic life resembling vegetation. These, and the "lunar canals" are matters that must be left to the expert selenographer. We need only say here that they are not yet accepted by astronomers generally without question.

Whatever may be the final judgment as to Professor Pickering's observations and theories, there is no question but that the photographic atlas will be found a useful and convenient guide to the amateur observer of the Moon. It is composed of eighty plates, reproduced without enlargement from as many negatives, which were taken by Professor PICKERING in Jamaica in 1901. His instrument was a twelve-inch lens of 135 feet 4 inches focal length. The Moon's equatorial diameter was divided into eight equal parts and perpendiculars drawn to it, cutting the lunar surface into sixteen areas. Each area was photographed five times, at lunar sunrise, noon, and sunset, and at two intermediate times, designated as morning and evening.

Examination of the atlas indicates that the negatives were generally good, but in many cases they have not been reproduced in a manner altogether satisfactory. Large-scale photographs like those issued by the Lick and Paris observatories are, of course, to be preferred for many purposes, but they are not readily accessible. The present atlas is on a scale sufficiently large for general use, and its completeness and systematic arrangement, together with its full index and its maps, should make it a useful and convenient guide. R. G. A.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE LIBRARY OF THE STUDENTS' OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA, AT BERKELEY, JANUARY 30, 1904, AT 7:45 P.M.

President VON GELDERN presided. A quorum was present. The minutes of the last meeting were approved.

The following new members were duly elected:—

LIST OF MEMBERS ELECTED JANUARY 30, 1904.

Mr. HERMAN JOHN DAVIS	369 Sutter St., S. F., Cal.
Mr. EDWARD DONOHOE	Donohoe-Kelly Banking Co., S. F. Cal.
Mr. D. S. GLOVER	2449 Webster St., Berkeley, Cal.

A committee to nominate a list of eleven Directors and Committee on Publication, to be voted for at the annual meeting, to be held on March 26th, was appointed as follows: Messrs. J. D. GALLOWAY (Chairman), J. K. MOFFITT, GEO. L. DILLMAN, WM. GRANT, H. E. MILLER.

A committee to audit the accounts of the Treasurer, and to report at the annual meeting in March, was appointed as follows: Messrs. CHAS. S. CUSHING (Chairman), L. H. PIERSON, D. SUTER.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE LECTURE HALL OF THE STUDENTS' OBSERVATORY AT BERKELEY, JANUARY 30, 1904 AT 8 O'CLOCK P.M.

The meeting was opened by an address of welcome by Dr. BENJAMIN IDE WHEELER, President of the University of California. President VON GELDERN then introduced the other speakers, who delivered the following addresses:—

Opening remarks, by Professor W. W. CAMPBELL.
The Students' Observatory, by Professor A. O. LEUSCHNER.
The Constant of Refraction, by Dr. R. T. CRAWFORD.
The Watson Asteroids, by Dr. B. L. NEWKIRK.
The Photographic Telescope, by Dr. A. F. GILLIHAN.

After the conclusion of the reading of the papers the audience was invited to inspect and use the different instruments of the Observatory

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. OTTO VON GELDERN	*President*
Mr. S. D. TOWNLEY	*First Vice-President*
Mr. W. W. CAMPBELL	*Second Vice-President*
Mr. CHAS. S. CUSHING	*Third Vice-President*
Mr. R. G. AITKEN Mr. F. R. ZIEL	*Secretaries*
Mr. F. R. ZIEL	*Treasurer*

Board of Directors—Messrs. AITKEN, BURCKHALTER, CAMPBELL, CUSHING, LEUSCHNER MOLERA, CROCKER, VON GELDERN, PIERSON, TOWNLEY, ZIEL.

Finance Committee—Messrs. PIERSON, CUSHING, LEUSCHNER.

Committee on Publication—Messrs AITKEN, SCHLESINGER, TOWNLEY.

Library Committee—Mr. TOWNLEY (*Librarian*), Mr. RICHARDSON, Miss O'HALLORAN.

Committee on the Comet-Medal—Messrs. CAMPBELL (*ex-officio*), PIERSON, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FELIPE VALLE.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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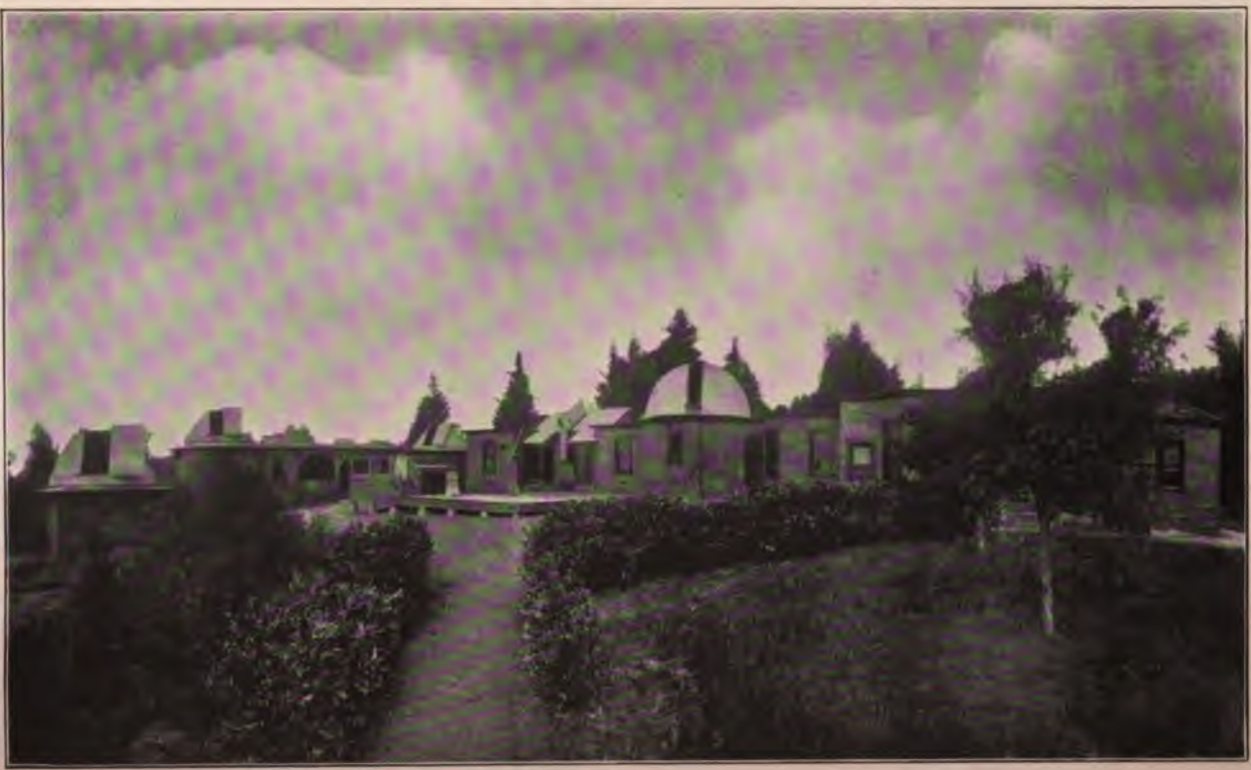

THE STUDENTS' OBSERVATORY, AT BERKELEY, CALIFORNIA.

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ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, IN AWARDING THE BRUCE MEDAL TO SIR WILLIAM HUGGINS.*

By OTTO VON GELDERN.

Another year in the history of the Astronomical Society of the Pacific has passed, and it becomes my pleasant duty, as your President, to review in some manner the aims and the accomplished work of the organization.

It is the object of the Society, and it has always been its object from the time of its founding, after the total eclipse of January, 1889, to foster astronomical science, not only among those who are professionally engaged in such a field of labor. but to awaken an interest for this, the Queen of all Sciences, in any one whose sole purpose in life is not the all-absorbing search after material welfare to the exclusion of everything else.

There can be no more fascinating study than that of the starry heavens; there is nothing around us that appeals so strongly to all the nobler sentiments of the human heart, to all the finer qualities of the human intellect, than a contemplation of the vastness of creation, the multiplicity of the population of space, and the overwhelming thought, What is there behind all this that seems forever destined to be shrouded in the deepest of mysteries? If there is ever a time when a man realizes his own smallness and insignificance it is when on a bright starry night he looks upward into the heavens and beholds the evidences of an endless creation. If this does not start within him an impression of the deepest awe, if it fails to touch his heart, and if it leaves his mind without that indescribable sense of man's dependence, he may indeed be pitied as an unfortunate, and as one who has not realized the ideals which the man of the twentieth century should cherish and foster.

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* The data for this address are from the Lick Observatory, the library of the Astronomical Society, and the Mechanics' Library.

The Astronomical Society attempts to reach such an ideal by awakening within any one an interest in the affairs of the heavens by a means somewhat different from the theologian, but nevertheless with a purpose fully as definite,—and that is, to help make better men and better women by an appeal to their intellect and their nobler faculties.

Our means to spread astronomical knowledge are not only these periodical lectures, but also the publications issued from time to time; the very excellent library; the summer visits to the Lick Observatory, and thereby the occasional touch with the men who devote their lives to this absorbing science.

Another means to help our members in attaining a knowledge of astronomical principles and astronomical methods of work has recently been added to those already mentioned, and I am very glad to take this opportunity of announcing to you that Professor A. O. LEUSCHNER, the head of the Berkeley Astronomical Department of the University of California, will offer exceptional opportunities to our members during the coming Summer Session of the University, for the purpose of giving the amateur astronomers the advantage of acquiring skill in the various modes of observation. He desires me to state to you the following, which I quote from his letter to me:—

> "There will be two courses offered by myself during the Summer Session, one of which will largely consist of practical observing with the many fine instruments now available at the observatory. It is my intention to form groups of such persons as may wish to avail themselves of the opportunities extended, and to enable each group to gain experience in one or more fields of observation. For example, some might be particularly interested in variable stars, others in spectroscopy, others in solar observations, others in planets, others in celestial photography, and others in various other observations with the transit instrument, sextant, or equatorials."

Here is certainly a rare chance for our enthusiastic members to gain a practical knowledge in astronomy, which would be impossible without appliances and without instruments. I think that Professor LEUSCHNER would be interested to hear from any one who may desire to learn the necessary details under which enrollment for this instruction is made possible.

With this short reference to the work of the Society, I, as your retiring President, congratulate you upon what has been accomplished, and hope that the future may be as bright as I would predict it. There is a field of usefulness before it, and we as members and interested individuals should never lose sight of the ultimate aim and the good mission which the Society has been created to fulfill.

With these heartfelt wishes I retire from my office, to leave it in hands abler than mine. Before doing so, however, there remains another duty to be performed, and I shall ask your indulgence for a short time to allow me to make a few remarks on the accomplished work of one of the great masters of the science that our Society fosters.

The Bruce Gold Medal of the Astronomical Society of the Pacific, founded by the late Miss CATHERINE WOLFE BRUCE, of New York, has been bestowed for the fifth time by the Board of Directors in conformity with the statutes governing the bestowal of this medal.

Those astronomers to whom it has been awarded previously are: SIMON NEWCOMB, of Washington, in 1898;
ARTHUR AUWERS, of Berlin, Germany, in 1899;
DAVID GILL, of Cape of Good Hope Observatory, in 1900;
G. V. SCHIAPARELLI, of Milan, Italy, in 1902.

This time the choice has fallen upon one of the best known of English astrophysicists, one who has probably done more in his particular field of research than any other astronomer, who may be considered as a pioneer in a field that has opened up so many new directions of investigation, leading to results constantly tending to broaden the knowledge and with it the intellectual horizon of man. I refer to the eminent scientist, Sir WILLIAM HUGGINS.

It becomes my pleasant duty to-night to announce to you the unanimous choice of this great man for the honors that lie within our power to bestow.

It is customary that in making a report like this to you a sketch of the life and the work of the medalist be added. Life-histories of eminent men written for purposes of this kind can at best but contain mere references to their labors and prominent achievements, and if in taking a cursory glance at the results accomplished by Sir WILLIAM HUGGINS in astrophysical science I should omit to mention even some of the most epoch-making discoveries, you will remember that in this particular case there are so many of them that a brief mention of what his labors have led to is all that can be attempted within the frame of an address like this.

WILLIAM HUGGINS was born in London, February 7, 1824. While his early education was received in the City of London School, it is very probable that his mind must have been awakened at a very early age to the realization of scientific fact, so that with his approaching manhood he had a practical knowledge of physical science. Study in microscopy upon animal and vegetable physiology had occupied his time to a considerable extent, and we hear of his becoming a member of the Microscopic Society in 1852.

But astronomy claimed his attention and became his chief pursuit, for in 1856 a private observatory for his studies was completed at Upper Tulse Hill, where he has constantly devoted himself to scientific investigations. At first they were probably confined to the measurements of the positions of celestial bodies, which was the principal work of the astronomer at that time.

Original minds with original thoughts are not likely to follow any prescribed course in whatever pursuit they may be engaged, and so in this case. The master mind must have conceived at once the great possibilities offered to astronomy by the discoveries and researches of KIRCHHOFF and BUNSEN, and when it was realized that spectrum analysis could be applied to the heavenly bodies, that they could be made to speak their own language, or write their own autographs, as it were, then astrophysical science was born, and disclosed an endless expanse of almost virgin soil, from which the human mind has harvested results as unique as they are marvelous.

This was the field of Sir WILLIAM HUGGINS, in which he has labored with ever-increasing success from the year 1862 until the present time. What he has accomplished in this period of over forty years has been the subject of numerous sketches and articles that have appeared from time to time in the scientific journals of the day.

In an address before the British Association our medalist makes this statement:—

"In 1866 I gave before this Association an account of the first-fruits of the novel and unexpected advances in our knowledge of the celestial bodies which followed rapidly upon KIRCHHOFF's original work on the solar spectrum and the interpretation of its lines.

"Since that time a great harvest has been gathered in the same field by many reapers. Spectroscopic astronomy has become a distinct and acknowledged branch of the science, possessing a large literature of its own and observatories specially devoted to it. The more recent discovery of the gelatine dry-plate has given a further great impetus to this modern side of astronomy, and has opened a pathway into the unknown of which even an enthusiast thirty years ago would scarcely have dared to dream.

"In no science, perhaps, does the sober statement of the results which have been achieved appeal so strongly to the imagination and make so evident the almost boundless powers of the mind of man. By means of its light alone to analyze the chemical nature of a far-distant body; to be able to reason about its present state in relation to the past and future; to measure within an English mile or less per second the otherwise invisible motion which it may have towards us or from us; to do more, to make even that which is darkness to our eyes light, and from vibrations which our organs of sight are powerless to perceive to evolve a revelation in which we see mirrored some of the stages through which the stars may pass in their slow evolutional progress,—surely the record of such achievements, however poor the form of words in which they may be described, is worthy to be regarded as the scientific epic of the present century."

The first researches were made with Professor W. A. MILLER, of Kings College, a chemist of note, who had made a practical application of spectrum analysis for a period of fifteen years. Their results were incorporated in the Report on the Spectra of Stars, sent to the Royal Society in 1863.

We know that starlight in passing through spectroscopic apparatus is severed into its constituent parts. The light is spread out into a band showing the usual prismatic colors. This band is crossed by lines and the spectroscopic problem is to read their meaning. Dark lines indicate to the spectroscopist that the light comes from an incandescent body, but has passed through cooler media,—that is, in its transmission some of it has been absorbed. Bright lines are evidences that the regions from which they hail are hotter than those below them, and an inspection of the star's spectrum may furnish us with valuable information regarding the physical condition of its atmosphere. Furthermore, the exact position of the spectral lines, and the method of measuring them, give a clew to the existing chemical composition of the origin of the light.

The spectra of many stars had been compared with those of several terrestrial elements, and it was found that they are hot bodies, similarly constituted to our Sun, and containing many of the substances found on the Earth. The spectra of the planets *Venus, Mars, Jupiter,* and *Saturn* had also been observed, and the results of these observations were made public in 1864. It is stated that the light from the planet *Uranus* was found too faint to be satisfactory for spectroscopic analysis; but an improved telescope in 1871 resulted in certain determinations showing its spectrum to be continuous, so far as the feebleness of its light permitted it to be traced.

While Fraunhofer, Lamont, and Donati had examined star spectra before, it must be remembered that the work of Huggins lay in an entirely different direction. As stated in an article published in *Nature*, by H. Kayser, in 1891, it was not simply the idea to see lines in the spectra of stars, but their chemical origin had to be determined; and therefore the light-gathering objective prism could no longer be used, but after the method of Kirchhoff and Bunsen a slit and comparison-prisms were employed. Finding this to weaken the spectrum to a great extent, and in order to broaden the point-like image of the star, his resourceful mind, ever ready to surmount difficulties, introduced the cylindrical lens, made for him by Browning.

In undertaking comparisons of spectra it soon developed that the data for such purposes were very insufficient, and Huggins undertook the labor of recording the position-lines of a great many elements. This work was of immediate value and proved a great success. Referring to that time, he states, in "The New Astronomy":—*

> "The observatory became a meeting-place where terrestrial chemistry was brought into direct touch with celestial chemistry. The characteristic light-rays from earthly hydrogen shone side by side with the corresponding radiations from starry hydrogen, or else fell upon the dark lines due to the absorption of the hydrogen in *Sirius* or in *Vega*. Iron from our mines was line matched, light for dark, with stellar iron from opposite parts of the celestial sphere. Sodium, which upon the Earth is always present with us, was found to be widely diffused through the celestial spaces."

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* June number of the *Nineteenth Century*, 1897.

He refers to the time as one of great expectation, for nearly every observation revealed a new fact, and a new discovery was made nearly every night. "And yet, notwithstanding," he continues, "we had to record that the inquiry in which we had been engaged has been more than usually toilsome; indeed, it has demanded a sacrifice of time very great when compared with the amount of information which we have been able to obtain."

As the field broadened the problems multiplied; they crowded themselves upon this original investigator, and while the first problem may have been solely this: What are those shining points of light upon the celestial dome?—there soon suggested itself a second one to his fertile brain, which, like a question whispered to him from the depths of space, asked: Whence came they?

In the year 1864 he began his original researches in a hitherto unexplored region,—that of the nebulæ. To this day there remains associated in his memory the profound awe which he felt on looking for the first time at that which the eye of man had never seen, and which even the scientific imagination could not foreshow.

The nature of these mysterious bodies was yet unknown; the view that they were parts of a fiery mist out of which the heavens had been slowly fashioned began to yield, based upon more recent telescopic investigations, to the opinion that all nebulæ may be capable of resolution into stars. In the "New Astronomy," already referred to, HUGGINS states:—

> "According to this view, nebulæ would have to be regarded not as early stages of an evolutional progress, but rather as stellar galaxies already formed, external to our system,—cosmical sand-heaps, too remote to be separated into their component stars."

It remained a question for a long time whether or not the nebulæ could be resolved into stars if a sufficiently powerful telescope could be brought to bear upon them.

The result of HUGGINS's investigations revealed a new scientific fact, and his spectroscopic analysis of the nebular light led to one of the greatest triumphs in astrophysics,—that is, that this phenomenon is not the result of crowding together separate and innumerable stars, but that it is accounted for by the presence of a mass of incandescent gas.

It was on the evening of the 29th of August, 1864, that HUGGINS directed his telescope for the first time to a planetary nebula in *Draco.* In speaking of this memorable event, he says: "Picture to yourself to some extent the feeling of excited suspense, mingled with a degree of awe, with which after a few moments of hesitation I put my eye to the spectroscope." It seemed to him as though he were about to gaze into Nature's secret place of creation.

He looked into the spectroscope and saw—not the expected spectrum, no! Only a single bright line! At first he suspected some displacement of the prism, and that he was looking at the reflection of the illuminated slit from one of its faces. But according to his own description, and in his own words, the true interpretation flashed upon him after a moment's thought. The light of the nebula was monochromatic, and so, unlike any other light as yet subjected to prismatic examination, could not be extended out to form a complete spectrum. After passing through the two prisms it remained concentrated into a single bright line, having a width corresponding to the width of the slit, and occupying in the instrument a position at that part of the spectrum to which its light belongs in refrangibility. A little closer looking showed two other bright lines on the side towards the blue, all the three lines being separated by intervals relatively dark.

He proclaimed:—

> "The riddle of the nebulæ was solved. The answer which had come to us in the light itself read: Not an aggregation of stars, but a luminous gas. Stars after the order of our Sun, and of the brighter stars, would give a different spectrum; the light of this nebula had clearly been emitted by a luminous gas."

Continued observations led to the conviction of the very great probability of an evolution in mighty space of starry creations going on from an unfathomable past into an equally unfathomable future. This master mind had grasped the birth of the stars; his keenness of intellect, quick to discern, as rapidly to combine, had deduced from the very signals of the stellar universe the genesis of its atomic life. It is when we ponder over such mighty results that we are overwhelmed with the capabilities of the human intellect. HUGGINS gives us his conclusions in the following words:—

> "A time surely existed when the matter now condensed into the Sun and planets filled the whole space occupied by the solar system, in the condition of gas, which then appeared as a glowing nebula, after the order, it may be, of some existing in the heavens. There remained no room for doubt that the nebulæ, which our telescopes reveal to us, are the early stages of long processions of cosmical events, which correspond broadly to those required by the nebular hypothesis in one or other of its forms."

Another important event in astrophysics was marked by his observations on a new star in *Corona Borealis,* to which his attention had been called by JOHN BIRMINGHAM on May 18, 1866. HUGGINS viewed the spectrum of this star on this evening, after it had already fallen in brightness below the third magnitude, and obtained a result up to that time unprecedented. The spectrum was that of the solar order, with its numberless dark lines, upon which appeared a few very bright lines. There was little doubt in his mind that at least two of these lines belonged to hydrogen. It led him to believe that an unusual brilliancy of these lines was due to a gas of higher temperature than that of the star's photosphere, and that suggested to him a cosmic catastrophe, a sudden and vast convulsion which had taken place in a star that from emitting but faint light had blazed up to one of second magnitude, falling again in brightness within the short period of twelve days to one of the eighth.

Volcanic forces or the disturbing approach or partial collision of another dark star may have been the cause of the sudden outburst. HUGGINS says: "The essential character of the explanation lay in the suggestion of a possible chemical combination of some of the escaping highly heated gases from within, when cooled by the sudden expansion which might give rise to an outburst of flame at once very brilliant and of very short duration."

In these three cases, taken from the early labors of our medalist, we have covered three periods of cosmic life. If the gaseous nebula may represent the cradle or birth of a sun, a world, or a system, the work upon the spectra of the stars led to a new knowledge of their chemical nature and relative physical conditions, and may appeal to us as exhibiting the various activities of existing individual cosmic life; while the last phenomenon referred to in the sudden brightness of an unknown member of the universe may represent to us its sudden destruction or tragic death.

But within these three stages of cosmic struggle there lay an enormous field of operation for this fertile mind, which was ever on the alert for new signals from the heavenly hosts.

The spectra of comets engaged his attention, and he found frequent opportunities to observe them. The faint comets did not lead to any very definite conclusions, but observations made on a bright wanderer in June, 1868, resulted in showing that the three bright bands, or flutings, of the spectrum agreed in position with three similar flutings in the brightest part of the spectrum of carbon. Very ingenious modes of comparison confirmed his expectation, and referring to the method and its results he states: "The comet, though subtle as Sphinx, had at last yielded up its secret. The principal part of its light was emitted by luminous vapor of carbon."

In 1881 an opportunity was offered for the first time to observe a bright comet by the spectroscope, fortified with suitable photographic plates, and this made it possible to extend the examination of its light into the invisible region of the spectrum at the blue end. The photograph brought to light a new fact; it led to the knowledge that nitrogen, as well as carbon and hydrogen, exists in comets.

Numerous systematic observations and original researches were made in his chosen special field of labor, all fruitful issues and events in the rapidly developing science of astrophysics. Fixed stars, nebulæ, comets, and possible new stars were compelled to yield their secrets to him. He devoted some attention to spectroscopic observation of the Sun, and also to the effects of sun-spots in their modification of the spectrum, and devised a method for determining the chemical constitution and the shape of the solar protuberances.

He sought for an explanation of the mysterious solar corona, to which he referred in his Bakerian Lecture for 1885, and in his Presidential Address before the British Association in 1891, and again in a short discussion of an explanation suggested by SCHEINER in 1900, in which he says that the matter of the corona is still open to questions of interest, and must be left for new information that may reasonably be expected from the observation of future eclipses.

The photography of star spectra occupied his time from an early period, for he attempted to obtain such spectra as long ago as 1864; but it was only after the dry-plate process became a reality that he successfully applied this art to the production of spectral images of celestial bodies, which led to many important and interesting discoveries. A book has been published by Sir WILLIAM and Lady HUGGINS (Lady HUGGINS was a former Miss MARGARET MURRAY, of Dublin, whom he married in 1875, and who became his acknowledged principal assistant and collaborator in his researches), in which the progress of photography of stellar spectra is given to the scientific world under the name of "Atlas of Representative Stellar Spectra," a magnificent volume, issued in 1899, with numerous illustrations and artistic chapter initials, by the talented Lady HUGGINS, which may give one an idea of the enormous and painstaking labor bestowed upon this most interesting and far-reaching feature of stellar spectroscopy; it has, indeed, been compared to a dictionary, for with a little stretch of the imagination one may call it "A Handbook of the Language of the Stars."

There remains a special subject in stellar spectroscopy not yet mentioned, but one that is so well known that I need hardly refer to it here, and that is the measurement of the motions of the stars in the line of sight. It is this work which has been taken up at the Lick Observatory, and in which Director CAMPBELL has gained such well-deserved recognition, and through whom this observatory (in the words of Professor NEWCOMB) has gained at once a position of pre-eminence, which it maintains to the present time.

Dr. HUGGINS, as early as 1868, presented to the Royal Society some observations on a small change of refrangibility in a line in the spectrum of *Sirius* as compared with a line of hydrogen. It was known that changes in the position of the lines of the spectrum might be used as an indicator and scale of the radial velocity of the object from which the light emanated, on the principle, suggested by DOPPLER sixty years ago, on which a sound becomes sharper or flatter accordingly as the ear and the sound-producing object approach or recede. This principle applied to the spectrum indicates an approach of the star if the lines are displaced toward the violet end, and a recession if this shift be toward the red end, providing that the displacement be not caused by pressure. The Earth's motion being known, the final result is the velocity of the star in the line of sight. Referring to his attempts to overcome numerous difficulties that presented themselves in this work, he says:—

> "At last, in 1868, I felt able to announce in a paper, printed in the Transactions of the Royal Society for that year, the foundation of this method of research, which, transcending the wildest dreams of an earlier time, enables the astronomer to measure off directly in terrestrial units the invisible motions in the line of sight of the heavenly bodies."

This method opened up a prolific field for spectroscopists, of whom a number have become very prominent. Improved methods of photography made it possible for Professor VOGEL to determine the motions in the line of sight of over fifty stars, with an accuracy of about an English mile a second. Other votaries, among them our lamented KEELER, have applied the method to a determination of the rotation of the Sun, of *Saturn* and his rings, and of *Jupiter*.

In the "New Astronomy" HUGGINS proposes a method of separating double stars too close to be individually visible. PICKERING and VOGEL have independently discovered by this means an entirely new class of double stars. In the publication above referred to he states that "it would be scarcely possible, without the appearance of great exaggeration, to attempt to sketch out, even in broad outline, the many glorious achievements which doubtless lie before this method of research in the immediate future."

I think this statement could be applied with equal force to all the different lines of research followed by him, every one of which has opened an avenue of approach to one of the richest mines of scientific labor. The life work of this eminent octogenarian lies open before us, and it is one well done and conscientiously performed. It seems opportune that I should quote from a recent book by Professor SIMON NEWCOMB, one of the most interesting that it has been my privilege to read. I know of nothing that has charmed me more than the perusal of the "Reminiscences of an Astronomer." And even fearing that in quoting from this book I may repeat in a measure what has already been dwelt upon, I shall relate to you what our first medalist has to say about the last:—

> "For the visiting astronomer scarcely a place in London has more attractions than the modest little observatory and dwelling-house on Upper Tulse Hill, in which Sir William Huggins has done so much to develop the spectroscopy of the fixed stars. The owner of this charming place was a pioneer in the application of the spectroscope to the analysis of the light of the heavenly bodies, and after nearly forty years of work in this field is still pursuing his researches. The charm of sentiment is added to the cold atmosphere of science by the collaboration of Lady Huggins. Almost at the beginning of his work, Huggins, analyzing the light of the great nebula of *Orion*, showed that it must proceed from a mass of gas, and not from solid matter, thus making the greatest step possible in our knowledge of these objects. He was also the first to make actual measures of the motions of bright stars to or from our system by observing the wave-length of the rays of light which they absorbed. Quite recently an illustrated account of his observatory and its work has appeared in a splendid folio volume, in which the rigor of science is tempered with a gentle infusion of art which tempts even the non-scientific reader to linger over its pages."

Sir William Huggins is now eighty years old, and, as we have seen, has been an active scientist for nearly half a century. Many are the honors that have been heaped upon him. He became President of the Royal Astronomical Society in 1876; President of the British Association in 1891; President of the Royal Society in 1900. He has received a Royal medal, the Rumford medal, and the Copley medal from the Royal Society, and two medals from the Royal Astronomical Society.

Is it not remarkable from what small beginnings this great scientific growth took its origin?—a piece of glass made into the shape of a wedge or prism, refracting the Sun's light, whose rainbow colors might be thrown upon a screen; a beautiful trifling toy that might delight a child.—and that is the spectroscope in its primitive form,—a simple glass, yet with an inherent power to wrest from the mighty universe its most mysterious secrets.

These are the seven colors recited by Sir William himself in poetic form:—

> "First the flaming red
> Sprung vivid forth; the tawny orange next;
> And next delicious yellow; by whose side
> Fell the kind beams of all-refreshing green.

Then the pure blue, that swells autumnal skies,
Ethereal played; and then, of sadder hue,
Emerged the deepened indigo, as when
The heavy-skirted evening droops with frost;
While the last gleamings of refracted light
Died in the fainting violet away."

That these beautiful colors, which God himself placed within the heavens as a symbol of his good will to man, contained more than a poetic meaning, that within them lay a language from the heavens that needed but an inspired interpreter to reveal, has been amply demonstrated by the life's labor of our medalist, Sir WILLIAM HUGGINS.

And in his absence, Mr. Secretary, I shall charge you with the mission of sending the medal to Sir WILLIAM, with our best wishes that he may live to see more years in which to enjoy the fruits of his accomplished work so modestly and unselfishly given to the world.

If our imagination can create the spectrum of a man's life, may his be to the end one crossed by bright lines only.

March 26, 1904.

PHOTOGRAPHS OF BORRELLY'S COMET (1903 *c*).

By SEBASTIAN ALBRECHT.

It is aimed in this paper to give a brief account of thirty-six negatives of Comet 1903 *c* (BORRELLY), obtained at Mount Hamilton between June 22d and August 18th, inclusive.*

Two distinct types of tails persist throughout the entire series of photographs. The principal tail is long and straight in its general direction, and in a large number of cases can be traced to the edge of the plate, a distance of ten degrees. It developed some very interesting forms, changing its aspect completely from day to day. Several more or less permanent features of the main tail deserve special mention. Its length was always considerable, and it was directed almost exactly away from the Sun. The mean deviation of the tail from the

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* A more complete account, with tables of measures and descriptions of the negatives, is published in *L. O. Bulletin* No. 52, and in the *Astro-Physical Journal*, March, 1904.

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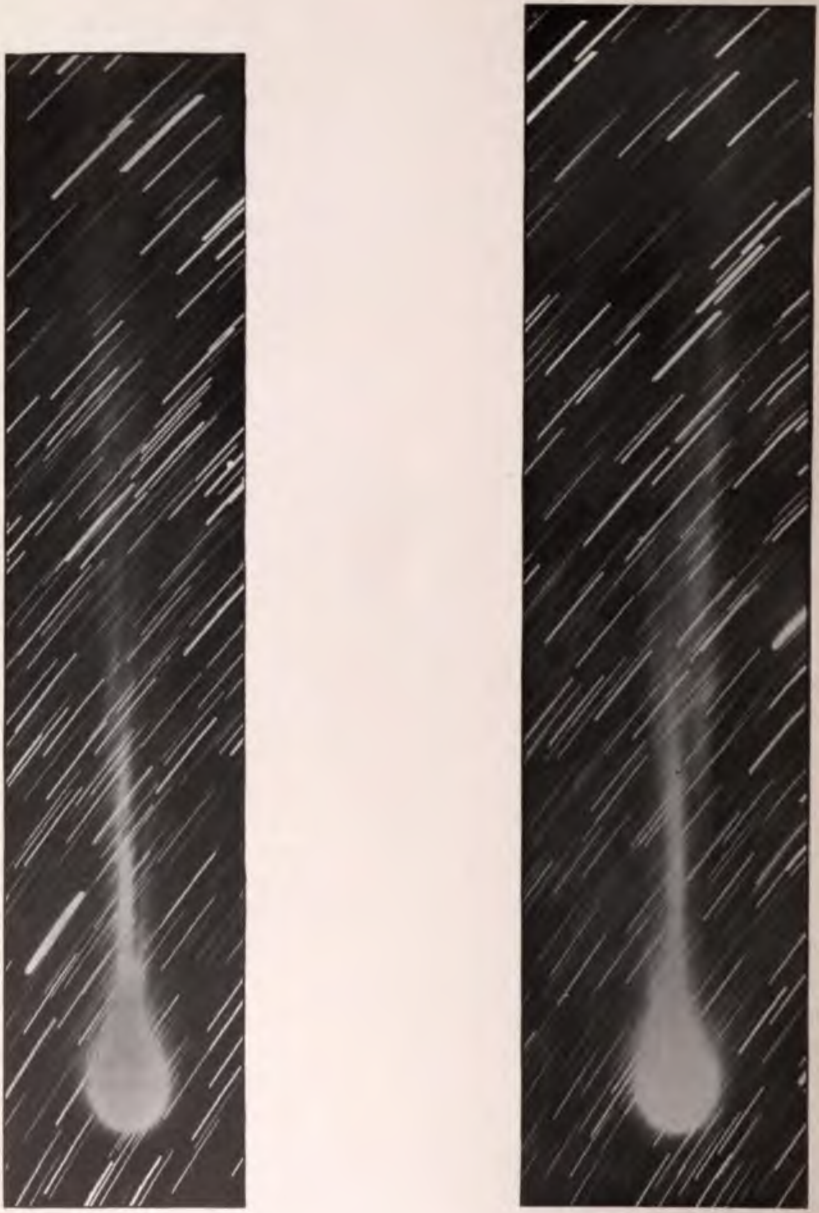


1903. July 23

1903. July 24

COMET 1903 *c*, [BORRELLY]

radius vector from the comet to the Sun was somewhat less than two degrees. The main tail, in general, widens out after leaving the head, and on a large number of plates divides into two distinct branches. From measures of the directions of the two branches of the main tail on eight plates, the mean angular distance between them was found to be about seven degrees. There is a marked contrast in the appearance of the primary tail on the negatives taken in July and on those taken in August. The tail on the plates of July is, with three exceptions, which will be mentioned later, smooth and continuous, while on the August plates it is twisted and full of condensations, indicating greatly increased activity as the comet approached perihelion.

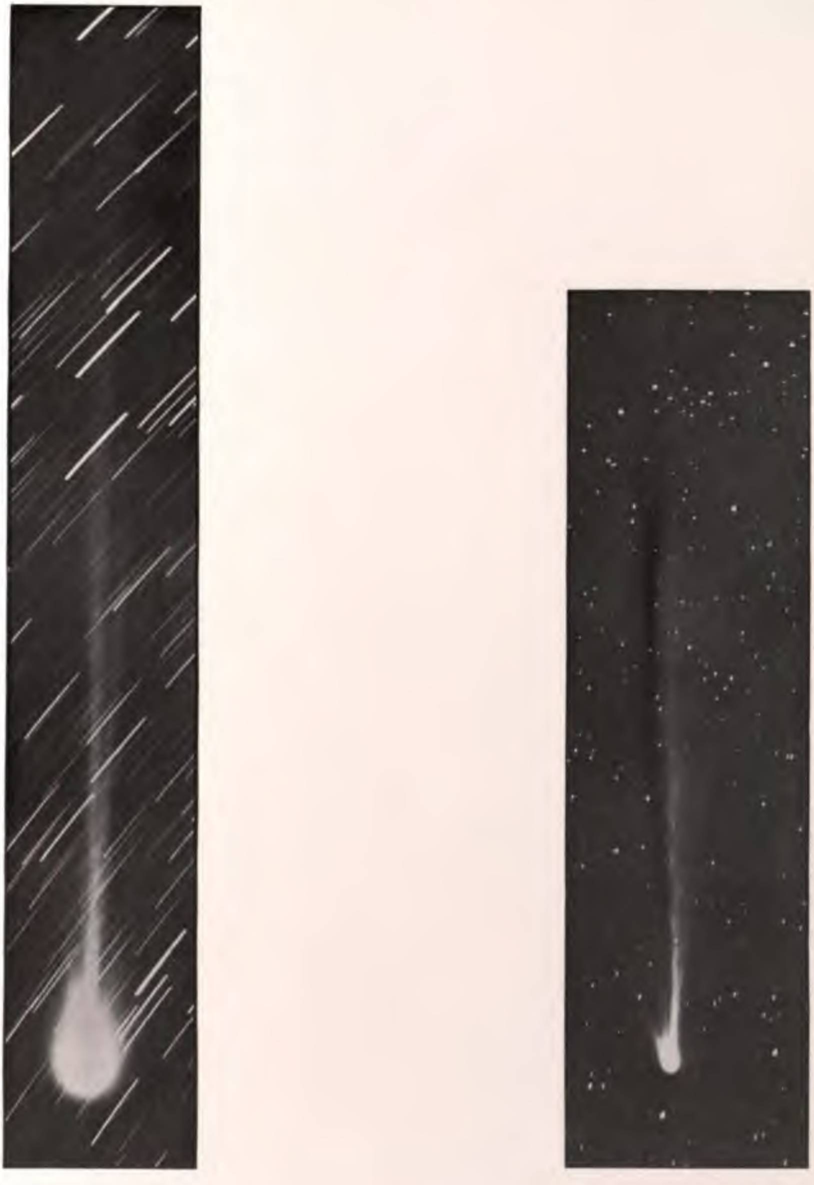
The other tail is short and very much curved, and presents practically the same appearance on all the negatives. It is bright even on the plates of June. Its length is about one and one half degrees. In the process of intensification necessary to reproduce the principal features of the primary tail, the coma has become so strongly intensified as to almost completely obscure the secondary tail. This is especially true for the plate of July 23d, where barely a trace of the short tail can be seen on the side opposite the new tail which appears on that plate. On the plate of June 22d the short tail made an angle of twenty-six degrees with the primary tail. This angle gradually diminished, owing to the foreshortening produced by the Earth's approach to the plane of the comet's orbit, until about the middle of July, when the two tails appeared to coincide. After the passage of the Earth through the plane of the orbit, the angle again increased until August 18th, when it amounted to thirty-three degrees.

In addition to these two tails, occasional streamers developed, some of which branched off from the main tail, while others issued directly from the head.

Three of the negatives, those of July 23d, 24th, and 26th, deserve special mention, on account of unusual structure in the principal tail. The plate of July 23d shows two long masses entirely separated from the main tail at about three and one half degrees from the nucleus, and on the side following the radius vector. One of these extends to the edge of the plate, a distance of about ten degrees from the head. The main tail extends to a distance of about five degrees from the head, and a long, narrow streamer leaves it about two degrees from the head. These four branches, together with two prominent bands in the main tail near the head, all making small angles with the general direction of the tail, present a wavelike appearance. The entire main tail somewhat resembles a rope, one end of which is unraveled and which has two of the loose strands severed.

The plate of July 23d shows, in addition, an entirely new tail issuing from the head in advance of the radius vector, preceding it by six degrees, but being bent toward the radius vector shortly after leaving the coma. This tail assumes the forked characteristic which the main tail shows on a majority of the plates. Its angular width is 4.6 degrees, and on the original negative it can easily be traced to a distance of four degrees from the head. The plate of July 24th does not record this extra tail. The plate of the 24th shows a detached section, preceding the radius vector, which is composed of two distinct portions, the shorter being nearer the head and pointing directly toward it. This can best be seen in the accompanying illustration by holding it obliquely, so that the eye is raised only slightly above the plane of the paper. This plate also records a detached streamer on the following side of the main tail, and directly opposite the detached section referred to above. The interval from the 23d to the 24th of July was evidently one of unusual activity. The plate of July 25th shows no unusual forms. The plate of July 26th shows the main tail broken at a distance of about three and one half degrees from the head.

From a comparison of the plate of July 24th with reproductions of two plates taken by Barnard and Wallace at the Yerkes Observatory and one by Quenisset at Nanterre, it was found that, in the interval of seven hours during which these photographs were taken, the detached section of the primary tail was receding from the nucleus at an average rate of thirty-five miles per second, which is equivalent to thirteen miles relative to the Sun.



1903. July 25

1903. August 12

COMET 1903 c, [BORRELLY]

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ASTOR, LENOX AND
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DEDICATION OF THE STUDENTS' OBSERVATORY, AT BERKELEY.

INTRODUCTORY REMARKS.

By Director W. W. Campbell.

(Before the Society at the meeting in Berkeley, January 30, 1904.)

There is probably no situation in which men and their work are more accurately judged than in a great modern university. The real and the superficial are almost unerringly sorted out by the open-minded and quick-witted students, by colleagues on the faculties, and by the conscientious and responsible heads of the institutions. The departments which seem to prosper year after year are really prosperous and are deservedly so.

One of the conspicuous features of university governments is an application of a very old truth—to the department that hath shall be given.

The addition to the Students' Observatory which we have met to dedicate this evening is an illustration of this fact. It is not to be thought of as an addition to California's list of properties; it is not simply a building containing a collection of astronomical instruments,—that would be a museum. Friends have presented the instruments, and the University has accepted, mounted, and covered them, with the expectation, based upon the record of the Department, that they will be used. They are an opportunity, and at the same time a responsibility. It is intended, I think, that they shall be employed for two main purposes: for giving instruction in the fundamental principles of the science, and for making original investigations, principally by the officers of the Department.

The elements of astronomy are taught more or less efficiently in a great number of American schools and colleges. Some of the teaching is real astronomy, and other portions are called astronomy by courtesy. The varieties differ as widely as the work of a local business college differs from that of a great metropolitan banking institution. Our colleges and universities which are successfully teaching the theory and practice of astronomy can almost be counted upon the fingers of the two hands. Nearly all of them make specialties of certain lines of astronomical work, depending upon the experience of the men in charge; and in these lines the instruction is of a very high grade. But there is, I think, no other American university in which real astronomy is taught so extensively as in the Berkeley Astronomical Department of the University of California. Taking into account also the astrophysical work and opportunities of the Department of Physics, and the encouragement and facilities extended, by fellowships and otherwise, to especially promising students at the Lick Observatory in all lines of research prosecuted there, the astronomical advantages of the University certainly seem to be unsurpassed. It is a pleasure to note that all the men who have taken advantage of them in the past few years have secured appointments to positions which afford them at least the opportunity to make suitable returns.

There is a strong and increasing demand for well-trained men and women to fill university and observatory positions, and I trust that the Berkeley Astronomical Department will have continually growing success in starting promising students on their careers in this pure science.

It is not desirable that these new instruments should cause individual students to spend more time on their undergraduate astronomy; but, rather, that they should spend the same amount of time more efficiently, and that a greater number of students should be attracted to the study of astronomy and have their requirements suitably met. If these instruments should entice the future astronomer away from simultaneous studies in the English language and literature, in history, in economics, and in other studies which broaden and balance him, then they would in fact be a detriment. Any undergraduate training in our science secured at the sacrifice of a liberal and broad education is a failure. No matter how excellent his special training, the young astronomer starts upon his profession badly handicapped if he is not proficient in speaking and writing his own language, and if he does not possess reasonable knowledge of many subjects apparently unrelated to his science.

In these days of great things one frequently hears the opinion expressed that for useful investigational work in astronomy powerful telescopes are demanded. It is true that recent advances in our science have been due in large part to the possession of powerful and expensive equipment. But the directors of observatories possessing such equipment are wisely restricting their programmes of work to those problems which cannot be solved equally well with small instruments; and it would be a grievous mistake to assume that the small telescope in suitable hands is not able to render good account of itself. Reference to the work of a few small telescopes makes interesting reading:—

The observations for ARGELANDER'S Durchmusterung, the work consulted more frequently than any other by astronomers, were made with a 3-inch refractor;

The Cordoba Durchmusterung, continuing the above work to the South Pole, is based upon observations made with a 5-inch telescope;

Nearly all unexpected comets are discovered with instruments not more than six inches in diameter, and great numbers of accurate determinations of their positions are made with the same telescopes;

Remarkable contributions to our knowledge of the forms and development of comets have been made in the past twelve years almost wholly with photographic telescopes from four to six inches in diameter;

Our comprehension of the elements which contribute to success in the difficult work of measuring the motions of the stars in the line of sight has increased until to-day we should be able to prove with a 6-inch telescope and a suitable spectrograph that *Capella* is a spectroscopic binary star whose two components, of nearly equal size, revolve around their common center of mass in 104 days;

The work of Dr. ROBERTS in the past ten years, in South Africa, on the photometry of variable stars, has been remarkable for its accuracy, quantity, and systematic nature; yet it has all been done with telescopes varying in size from one to three inches;

KEELER'S spectrographic observations of the velocities in the ring system of *Saturn*, in my opinion, constitute the most beautiful individual observation made in recent times; yet his telescope, located in a region notorious for its poor atmospheric conditions for such work, was only thirteen inches in diameter.

In closing this informal address. I beg to relate an incident which bears upon the question of the success of the excellent and beautifully finished new instruments which we are invited to inspect at the close of this meeting: In the year 1893, a prominent citizen of California, connected at the time with the educational system of the State, visited the Lick Observatory and inspected its instruments. I well recall his expression of disapproval when he saw that the brass tube of the Crocker telescope, with which Professor **Barnard** was securing his famous photographs of the Milky Way and comets, looked worn, and did not carry the polish which one sees on the companion-rail of a steamship. And later in the day, when the star spectroscope, which Professor **Keeler** had used so successfully in measuring the motions of the planetary nebulæ, and in investigations on objects of special interest, was seen to be worn and scratched from five years' continual use, it was remarked, quite forcibly, that we did not seem to be taking very good care of our instruments.

The most comprehensive good wish that I can make for the Berkeley Astronomical Department, in whose success we all rejoice, is, that when the Astronomical Society of the Pacific is again invited to hold a meeting in the Students' Observatory we shall find the varnish worn away from many parts of these new instruments.

HISTORY AND AIMS OF THE STUDENTS' OBSERVATORY.*

By A. O. Leuschner.

The buildings and equipment which we dedicate to-night bring us considerably nearer to the realization of the hope of having at the University of California a well-equipped Students' Observatory. Our hearts are full of gratitude to those who have helped us meet our most pressing needs.

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* Address delivered before the Astronomical Society of the Pacific, January 30, 1904, at the dedication of the new observatory buildings of the University of California. Rewritten for the *Publications* of the Astronomical Society of the Pacific.

On behalf of the Berkeley Astronomical Department, I thank Mr. WILLIAM M. PIERSON for the gift of his splendid eight-inch reflector; Mrs. HERMAN OELRICHS, for the donation of the late Senator FAIR'S five-inch refractor; the President and the Hon. Board of Regents, for the erection of suitable buildings; and last, but not least, again, President WHEELER, who is ever taking a keen interest in all that concerns our students, for causing the regular budget of the Students' Observatory to be increased so as to enable us to make material additions to our equipment. The total value of our new possessions is over nine thousand dollars, the value of the new equipment alone being over five thousand dollars. Our thanks are also due to Professor JOHN GALEN HOWARD, Supervising Architect of the University, and his staff, for the care taken in meeting our requirements, with reference to the design of the new buildings, and to the California School of Mechanical Arts, particularly to Messrs. G. A. MERRILL and E. T. HEWITT, for their aid in the construction of the photographic telescope and the running-gears of the new domes. Dr. A. F. GILLIHAN and Mr. VAL. ARNTZEN are to be particularly complimented for the energy and efficiency displayed by them in the construction of the photographic telescope and in putting our new equipment in place.

The new buildings are intended to be temporary, and are constructed of wood. They consist of a main building, with domes for the Oelrichs and photographic telescopes, and a separate dome for the Pierson reflector. The main building extends north and south on the west slope of the hill on which the Students' Observatory is situated, and faces east. It contains, aside from the domes, two large rooms, 30 x 30 and 20 x 30, on one floor; also a photographic dark-room and store-rooms in the basement. The reflector dome is located on the south slope of the hill.

The new equipment includes the Pierson (Newtonian) reflector, of 8 inches aperture and 6 feet focal length, by BRASHEAR; the Oelrichs refractor, of 5 inches aperture and 6⅓ feet focal length, lens by ALVAN CLARK and mounting by GAERTNER & CO., Chicago; a mounting designed and constructed in the University for the Harrison portrait-lens, of 5½ inches aperture and 22 inches focal length, a Repsold measuring-apparatus for measuring positions on photographic plates, and a Gaertner comparator for measuring spectrograms.

In addition to these improvements a wooden platform surrounding three piers has been erected in the open space between the old and new buildings, for use as an open-air observatory with portable instruments. The three instruments in question, which have been loaned to the department, are a 3-inch equatorial of 4 feet focal length, a 1¾-inch Browning transit-instrument, and a 1⅛-inch altazimuth instrument, with circles graduated to 5″.

Our new acquisitions are primarily intended to increase the efficiency of our instruction in practical astronomy, but they will also afford the members of the department considerable opportunity for original observation.

The Students' Observatory of the University of California occupies a unique position among the astronomical observatories in this and other countries. Founded originally for the purpose of giving a few civil-engineering students the astronomical knowledge necessary to their profession, its development ever since has been in the direction of creating new opportunities for the study of astronomy in all its branches, until now it is well recognized that the University of California, with its two astronomical departments—the Lick and the Berkeley—has a well-organized and prominent training-school for the profession of astronomy. It was through the efforts of Professor FRANK SOULÉ, head of the Department of Civil Engineering, ably assisted by Professor WILLIAM THOMAS WELCKER, then Superintendent of Public Instruction, that an appropriation of ten thousand dollars for the erection of a Students' Observatory was secured from the Legislature of the year 1885. The appropriation was most wisely and economically expended, about one half being applied to the erection of the necessary building and one half to equipment.

Instruction in this little observatory commenced in the fall of 1887. I well remember the fine impression which the observatory made upon me when I first visited the same in 1889, during my career as a student in the Lick Observatory. Coming down from the great Lick Observatory, with its huge and magnificent instruments and perfect equipment, the Students' Observatory impressed me as a neat and complete model of what a large observatory should be.

The observatory building then consisted of the dome, housing the 6-inch equatorial of 8⅓ feet focal length; the small instrument-room for minor apparatus; the transit-room, containing the 3-inch Davidson zenith and transit telescope; the Howard mean-time clock, the chronograph, and the switchboard; and two small rooms. A small house in the rear harbored the Ewing, Gray, and Duplex seismographs. The minor equipment included a spectroscope, sextants, chronometers, level-trier, and spherometer.

Since then the observatory has been enlarged four times, by the addition of a computing-room, 17 x 30; an office for the Director; a lecture-room, seating 200 students; and the buildings which are being dedicated to-night.

In the earlier days the headquarters of the Department of Civil Engineering and Astronomy, of which the Students' Observatory formed the other part, consisted of one room on the top floor of North Hall. The head of the department and one instructor made up the staff. It was not long before the burden of carrying the instruction in civil engineering as well as in astronomy became so great that Professor SOULÉ was forced to ask to be relieved of the latter, and in 1892 the courses in general and practical astronomy, offered for the benefit of the civil-engineering students, were assigned to me while I still retained my connection with the Department of Mathematics.

It was at this time that the tremendous possibilities in the University of California for the development of a successful department of instruction first impressed themselves upon me.

The ideals which since then have constantly been kept in mind were first to shape the undergraduate work in astronomy so that upon graduation the student would be found fully qualified to take part as an assistant in the regular work of a large observatory, and then to develop graduate instruction in such lines as could be satisfactorily undertaken at Berkeley. At the same time the original purpose of the observatory—to afford the necessary instruction in astronomy and geodesy to civil-engineering students—has been carefully adhered to. Provision has also been made for special instruction in navigation and nautical astronomy for students in the College of Commerce. Aside from these functions of the observatory, which provide instruction for students with specific views in mind, the department has organized general lecture and observatory courses, open to all students of the University, for the benefit of those who wish to familiarize themselves with the fundamental principles of astronomical science. their philosophy and historical development. In these courses special attention is paid to modern methods of research and new discoveries. Among others, the course in modern astronomy is given jointly by the Lick and the Berkeley Astronomical Departments and every member of the University enjoys, therefore, the opportunity of being brought into immediate contact with the most recent work of our great Observatory at Mount Hamilton.

That there always has been and now is call for a thorough training-school for the astronomical professions needs hardly to be emphasized. Perhaps no science attracts the popular fancy more than astronomy. As a result many gifted men and women acquire small telescopes and devote themselves as amateurs to a certain limited class of observations, often reaching therein a perfection which places their names prominently before the world. A university should extend to them every opportunity to combine with their enthusiasm, energy, and brilliancy a profound knowledge of the necessary principles of mathematics, physics, and astronomy. Many university graduates who in their undergraduate career plan to become astronomers later find that the institutions which they have attended were not prepared to give them the necessary instruction and guidance.

The necessity of a thorough preparation for the professions of medicine, law, and engineering has long been recognized, and the energies of most universities are bent on offering the best possible preparation for them. Of the pure sciences none is so much in need of similar attention as astronomy, as it depends in an unusual degree upon allied sciences, particularly upon mathematics and physics.

The question, however, might arise whether or not the organization of a department of instruction in astronomy at Berkeley would involve a serious and undesirable duplication of the work of the great Lick Observatory, which forms an integral part of the University. We might ask ourselves whether a university should abandon its medical instruction because it is in touch with famous hospitals. Would the hospital work be of benefit to any one but a qualified student for further experience? Is such a university not all the more under obligation to organize the best possible medical instruction, so as to give its young doctors the full benefit of the available hospital opportunities? Or would it be feasible to attempt the instruction in the various branches of science upon which medicine depends in the hospital itself? And, further, ought graduate or research work in astronomy be attempted at Berkeley? Is not the work of our new Physiological Laboratory under Professor LOEB of the highest importance to medical science? Is there not research work in astronomy which is similarly related to the observational work of a great observatory? Among others, *theoretical astronomy* and *celestial mechanics* certainly are.

The two directions in which the energies of the department at Berkeley ought to be applied, clearly defined themselves at the outset, and ever since the aim of the department has been to develop elementary and advanced instruction in all branches of astronomy, and to organize, in particular, graduate and research work in theoretical astronomy and celestial mechanics.

Thus our aims have been to supplement rather than duplicate the work of our great Observatory at Mount Hamilton. No astronomical department, however, can be of great service to intending astronomers without the hearty co-operation of other departments, particularly of mathematics and physics. It is only fitting that on this occasion acknowledgment should be made of the hearty co-operation which the heads of these departments in this University have shown at all times in providing for the needs of our astronomical students.

The first important step in the development of our so-called "School of Astronomy" was taken in 1894, when the College of Civil Engineering organized a special undergraduate course in astronomy and geodesy. With the organization of our College of Natural Sciences and the growing demand for instruction in pure astronomy, this course was taken out of the College of Civil Engineering. A few years later the Students' Observatory was separated from the Department of Civil Engineering and Astronomy, the new department receiving the name of "Berkeley Astronomical Department."

A new impetus was given to the efficiency of the work of higher instruction in astronomy in 1898, when, at the recommendation of Director KEELER, a vacancy in the regular staff of the Lick Observatory was filled by the appointment of three graduates of the University of California to fellowships in the Lick Observatory, with the priviiege of spending one term each year in graduate work at Berkeley.

When I made a suggestion in this direction to Professor KEELER on the day of his arrival in California, he expressed his doubts as to the value in a large observatory of young graduates whose sole experience consisted in the astronomical work done as undergraduates, but he agreed to try the experiment for one year. A few months later, at a meeting of the heads of departments at Berkeley, he expressed regret that more fellowships were not available for our graduates. Since then the Lick and the Berkeley astronomical departments have commenced to vie with each other in meeting the needs of graduate students.

While at first the time of Fellows at Mount Hamilton, by force of circumstances, was much taken up with ordinary routine work, Director CAMPBELL is lending his energies more and more to create for them opportunities and facilities for original research, so that it would seem that at present, through the co-operation of the various departments concerned, the organization of the instruction in astronomy and its allied subjects, particularly for candidates for the degree of Doctor of Philosophy, leaves little to be desired.

The University of California has already turned out a formidable array of young astronomers. Some of its graduates are at the head of astronomical departments in Eastern institutions. The two men who compose the staff of the Mills Expedition of the Lick Observatory to South America were first introduced to the science of astronomy in this building. One man is a research assistant in theoretical work under Professor NEWCOMB in the Carnegie Institution at Washington. Several are rapidly rising in the United States Coast and Geodetic Survey. One is instructor in this department, and so on. Eight have been found worthy of appointment to fellowships in the Lick Observatory. In this connection, it may be stated that only students who give evidence of exceptional qualifications as accurate observers and computers, and of ability for original research, are recommended by the Berkeley Astronomical Department for admission to the Lick Observatory.

Many students of astronomy turn their eyes to California for the completion of their training. During the few weeks which have elapsed since the opening of the current semester, this department has received no less than four applications from men and women already actively engaged in astronomical work, with reference to the conditions on which they might continue their theoretical work at Berkeley, and no doubt Director CAMPBELL receives even more applications from advanced students who desire to profit by the unexcelled opportunities of the Lick Observatory.

Thus our efforts seem not to have been in vain. Not long ago, Professor NEWCOMB was reported to have stated that there were two things standing out prominently in astronomical science of to-day: on the one hand the never-ceasing flow of new and startling observational results from the Lick Observatory, and on the other the production of men, well trained for their profession, in the University of California.

It is our constant aim to turn out men who are not merely astronomical practitioners, but *scholars* in the true sense of the word. It is scholars who are needed in astronomy—men capable of promoting science.

An outline of the various courses of instruction offered to astronomical students has been printed by the University under the title "Announcement to Students" by the Lick Astronomical Department and the Berkeley Astronomical Department. It may not, however, be without interest to state here a few characteristic features of the instruction given in this department. First of all, we make it clear to students who desire to prepare for an astronomical profession that their chief reward in later life will consist in the satisfaction which they will derive from their work. Only those who prove themselves to be exceptionally well fitted for astronomical work are encouraged to continue their studies. The quality of the students enrolled, and not numbers, count in our advanced classes. At all times a close personal contact between students and instructors is preserved, the student sharing whatever problem the instructor may be engaged upon.

In the practical courses we have no set programme of observations and reductions. A student is kept at work from the very beginning with the same instrument—generally the sextant—until he can use it with the skill of an experienced astronomer. This means slow progress at first, but our experience has taught us that the student who thoroughly masters one instrument is not satisfied until he can handle every other instrument equally well. It is in this way that the student will gradually acquire that taste for thoroughness and accuracy so characteristic of BESSEL. With the instrument which he has mastered the student takes part in such work as the observatory undertakes from time to time. Students are not taught to do approximate work first, but the greatest accuracy is aimed at from the outset. Approximate work where it is sufficient can only then be done intelligently, when the subject is first thoroughly mastered. Problems are selected which require the greatest skill. Thus by stellar distances students have determined with great accuracy the eccentricities of our sextants and have determined the longitude by lunar distances. In practice the last-named experiment has become obscure, but its training value cannot be underestimated. By the telegraphic method students have furnished the observatory with accurate determinations of the differences in longitude between Berkeley, Mount Hamilton, and San Francisco. Extended latitude series by TALCOTT's method are available for discussion; similarly, comets, asteroids, and variable stars are observed from time to time, etc.

In theoretical work the same thoroughness is aimed at. Independent thought is cultivated in students, as well as a critical attitude toward what they receive in lectures or from books. Mechanical reduction of observations without a thorough knowledge of the subject is distinctly discouraged. In the theory of orbits a comparative study is made of the various methods proposed for deriving the elements of newly discovered comets or asteroids, with a view to enable the student to select in a given case the method best suited to the solution of the orbit on the basis of the underlying conditions. A senior, before graduation, is expected to be ready to calculate at a moment's notice a preliminary orbit and ephemeris of a newly discovered comet or asteroid.

This work has been extensively practiced in the past, and on more than one occasion students of this University were the first to announce the orbit of a new comet. By making the student participate in the real astronomical work of the day, his ambition and enthusiasm are constantly stirred.

The numerical determination of the perturbations of the Watson asteroids supplements the work in the seminary or the lecture-room.

A great part of the scientific output of the Students' Observatory must be considered to consist in the later achievements of the men who go forth from it. Owing to the large amount of time devoted to the training of students the members of the department are naturally handicapped in prosecuting their own researches. It is not uncommon for us to find ourselves called upon to drop our own investigations at a critical point, in order to assist a student in his work. Nevertheless, we have been able to publish some observations and theoretical investigations which are not without value, and several important papers are now awaiting the finishing touches for publication.

This account of the aims and the history of the Students' Observatory would not be complete without touching upon some of the wants still felt. Aside from the new observatory which is to form part of the Greater University under the PHŒBE HEARST plans, this department needs above all the establishment of some scholarships or fellowships.

I trust that the members of the Astronomical Society of the Pacific, whom we so gladly welcome here to-night, and who I hope will be seen frequently in these buildings hereafter, will aid us in our ambitions. Perhaps some day they may wish to make their headquarters on these grounds, thus benefiting themselves and us by closer contact with one another.

THE CONSTANT OF REFRACTION.

By Russell Tracy Crawford.

(Read before the meeting of the Society held in Berkeley, January 30, 1904.)

The phenomenon known as refraction was first mentioned by and probably discovered by Ptolemy, who lived about the second century A. D. In his famous treatise on optics he points out that the light coming to us from a star or heavenly body, on entering our atmosphere and traversing it to its lower and denser portions, is gradually bent or *refracted,* the result being that the object appears to the observer to be nearer the zenith than it actually is. He shows further that this bending ranges from zero at the zenith to a maximum at the horizon.

Walther, who worked in the fifteenth century A. D., was the first one to make any successful attempt to allow for atmospheric refraction in reducing observations.

Tycho, who is celebrated for his wonderful series of accurate observations, recognized fully the importance of refraction, and consequently made a series of observations to find out the amount of displacement of an object, due to this bending for different parts of the sky, and constructed the first table of refraction. Although it was not a very accurate one, it marks an epoch in the study of this phenomenon. Kepler, following Tycho, made a considerable improvement in the theory of astronomical refraction.

The law of refraction was discovered by Snell in the early part of the seventeenth century. In the latter part of this same century, Cassini computed a new table of refractions which was an improvement upon Kepler's. This was, in turn, followed by a further improvement by Bradley in the early part of the eighteenth century.

About 1818 Bessel gave us his theory of refraction, which is the one used to-day. "Although the complete theoretical solution was then, as now, unattainable, he succeeded in constructing a table of refractions which agreed very closely with observations, and was presented in such a form that the necessary correction for a star in almost any position could be obtained with very little trouble."

The importance of refraction in any problem involving, either directly or indirectly, the zenith distance of an object is evident. The amount of the bending depends upon two things, the density of the air surrounding the observer, and the angle at which the ray of light strikes the refracting medium. As for the variation with the angle of incidence, we may say that refraction varies (very nearly) directly as the tangent of the angle of incidence. The density of the air depends principally upon the elevation above sea-level, and the temperature. BESSEL'S theory takes account of all these things, and in this theory is involved what is known as the constant of refraction.

We might now ask what we mean by the constant of refraction, or what is the constant of refraction. It is *not* a number representing something of which we can form a definite picture, as we can of the constant of aberration, for instance, which is the angle whose tangent is the ratio of the velocity of the Earth in its orbit to the velocity of light; but it is one of two numbers which enter as constants into the general expression of refraction, and cannot be described in words, but merely represented analytically. These two constants are usually designated α and β; but the one called α is known as *the* constant of refraction.

The values of these constants may be found from theory by making some assumption as to the law of the decrease of density of the air for increasing heights above the surface of the Earth. Several such assumptions have been made and tables of refraction deduced from them; some of them give values of the refraction which agree fairly well with observations for a short distance from the zenith, but fail utterly for large zenith distances. The hypothesis presented by BESSEL, however, holds very well indeed for all zenith distances down to about 85°. It is upon this hypothesis that modern refraction tables are based.

First, then, tables were made from these theoretical values of the constants, and corrections have since been made to them by making use of the discrepancies found to exist between the theoretical values of the refractions and the actually observed values. These discrepancies are small; so small, in fact, that we may regard the formula for refraction, which involves these constants, as representing the *law of refraction* well enough, but they are too large to give very fine results, such as are needed in work with the meridian-circle. The constants of refraction, therefore, must receive small corrections in order to make theory and observation harmonize. The constant β is small, and is undoubtedly very accurately known, so that our attention, for the present, will be directed wholly to *the* constant of refraction, a.

Considering, then, that no correction to β is needed, the following equation can be shown to exist:—

$$dr = \frac{r}{a} da$$

in which r is the refraction, a the constant, dr the difference between the observed and the computed refraction, and da the small correction to be applied to the constant, upon which the computed refraction depends, to obtain the constant which will agree with the observations.

The whole problem, therefore, resolves itself into finding some means of deriving the true refractions from observations so that we may form the quantity dr. There are several methods of obtaining refractions from observations. The one generally used, and which gives excellent results, is by observations of circumpolar stars. I shall explain this method in the words of Young, taken from his General Astronomy:—

"With an observatory whose latitude exceeds 45° select some star which passes through the zenith at upper culmination. It will not be affected by refraction at the zenith, while at the lower culmination, twelve hours later, it will. With the meridian-circle observe its polar distance in both positions, determining the 'polar point' of the circle in the usual way. If the polar point were not itself affected by refraction, the simple difference between the two results for the star's polar distance, obtained from the upper and lower observations, would be the refraction for the lower point.

"As a *first approximation*, however, we may neglect the refraction at the pole, and thus obtain a *first* approximate lower refraction. By means of this we may compute an *approximate* polar refraction, and so get a first 'corrected polar point.' With this compute a second approximate lower refraction, which will be much more nearly right than the first; this will give a second 'corrected polar point': this will in turn give us a third approximation to the refraction; and so on. But it would never be necessary to go beyond the third, as the approximation is very rapid. If the star does not go exactly through the zenith, it is only necessary to compute each time approximate refractions for its upper observation, as well as for the polar point."

This method, as I have said, gives excellent results, but it has several disadvantages, which it might be well to note. In the first place, it is easily seen that the computations required are quite complicated because of the approximations which have to be made; further, the latitude and its variation are involved; again, the field of observation is limited; and finally, there must be a wait of twelve hours or six months between the observations at upper and lower culminations. If this wait is twelve hours, one observation, in general, will be made in the daytime under entirely different atmospheric conditions from the one made at night; if the wait is six months, so that both observations may be made at night, the atmospheric conditions will again probably be entirely different at the times of the two observations.

It is my purpose now to present briefly another method by which refractions may be observed. It may be stated as being a "quasi" converse to TALCOTT's method of determining latitude. Instead of eliminating refractions to get the latitude the method is to determine the refractions by eliminating the latitude, as follows:—

Let z_s = the zenith distance of a southern star.
z_n = the zenith distance of a northern star.
z'_s = the apparent zenith distance of the southern star.
z'_n = the apparent zenith distance of the northern star.
δ_s = the declination of the southern star.
δ_n = the declination of the northern star.
r_s = the refraction of the southern star.
r_n = the refraction of the northern star.
ϕ = the latitude of the meridian-circle.

Then
$$\delta_n = \phi + z_n = \phi + (z'_n + r_n) \tag{1}$$
$$\delta_s = \phi - z_s = \phi - (z'_s + r_s) \tag{2}$$
$$\delta_n - \delta_s = z'_s + z'_n + r_s + r_n \tag{3}$$
Let
$$A =: \delta_n - \delta_s \tag{4}$$
$$B = z'_s + z'_n \tag{5}$$
Then
$$A = B + r_s + r_n \tag{6}$$
or
$$r_s + r_n = A - B \tag{7}$$

If now the southern and northern zenith distances were the same, and if, at the times of observing them, the conditions of the atmosphere were the same, the two refractions would be the same,—i. e.—

$$r_s = r_n$$

In this case we have

$$2r = A - B \qquad (I)$$

In practice these ideal conditions are only approximately satisfied. We therefore proceed as follows:—

From (7) we have

$$2r_s - r_s + r_n = A - B \qquad (8)$$

whence

$$2r_s = (A - B) + (r_s - r_n)$$

and

$$\left.\begin{aligned} r_s &= \tfrac{1}{2}(A - B) + \tfrac{1}{2}(r_s - r_n) \\ r_n &= \tfrac{1}{2}(A - B) + \tfrac{1}{2}(r_n - r_s) \end{aligned}\right\} \qquad (II)$$

also

In case the northern star is at lower culmination we shall have:

$$\delta_n = 180^\circ - z_n - \phi \qquad (9)$$

$$\delta_s = \phi - z_s \qquad (10)$$

$$\delta_n + \delta_s = 180^\circ - z_n - z_s \qquad (11)$$

$$= 180^\circ - [z'_n + r_n + z'_s + r_s] \qquad (12)$$

Hence

$$r_n + r_s = 180^\circ - [z'_n + z'_s] - [\delta_n + \delta_s] \qquad (13)$$

and

$$2r_s = 180^\circ - [z'_n + z'_s] - [\delta_n + \delta_s] + [r_s - r_n] \qquad (14)$$

Calling

$$A' = \delta_n + \delta_s \qquad (15)$$

and since

$$B = z'_s + z'_n \qquad (5)$$

we have

and

$$\left.\begin{aligned} r_s &= 90^\circ - \tfrac{1}{2}[A' + B] + \tfrac{1}{2}[r_s - r_n] \\ r_n &= 90^\circ - \tfrac{1}{2}[A' + B] + \tfrac{1}{2}[r_n - r_s] \end{aligned}\right\} \qquad (III)$$

In order to obtain the refractions from (II) and (III) it is necessary to know the declinations of the stars, their apparent zenith distances (or, rather, the sums of the zenith distances of the pairs of north and south stars), and the differences between the refractions of the pairs.

Observations were made at the Lick Observatory by myself, in accordance with this method during a few months of 1899. The stars used were all fundamental, and in a first approximation their declinations are to be considered absolute. They were taken from Professor NEWCOMB'S "Catalogue of

Fundamental Stars for 1875 and 1900, Reduced to an Absolute System." The apparent zenith distances, or the sums of the zenith distances of the several pairs, are obtained from the meridian-circle observations; and the differences in the refractions are found by computing the refractions from some standard table. In this work the Pulkowa tables have been used. The term ½ $(r_s - r_n)$ being of the nature of a differential refraction, any error in the constant of refraction of the table used will have practically no effect upon this difference. The more nearly ideal conditions (i. e. when $r_s = r_n$) are approached, of course, the better the determination of the refractions will be.

This method has both its advantages and its disadvantages. Among the former, the most important are: First, the total elimination of the latitude, and hence also of its variation; second, the elimination of the nadir, since $(z'_s + z'_n)$ is nothing more nor less than the difference between the circle-readings, and is therefore independent of the zenith point; third, there is no wait of twelve hours or of six months in order to observe a star at both culminations, as is usually done; and fourth, the simplicity of the reductions.

The greatest disadvantage in this method lies in the fact that the declinations of the stars have to be considered known. But by taking fundamental stars, such as those whose places are given by Professor NEWCOMB's new Fundamental Catalogue, and by taking a large number of these stars, this difficulty will be nearly completely eliminated.

The value of the constant found from these observations, reduced by the method just given, is somewhat smaller than that used in the Pulkowa refraction tables. It is 60″.159 for a pressure of 760^{mm} at 0° and 0° (C.) temperature.

For the sake of comparison, the most important determinations of the constant of refraction are given below. These values are for the conditions $B = 760^{mm}$ at 0° C. and external thermometer = 0° C. (These values are taken from Professor BAUSCHINGER's "Untersuchungen über die Astronomische Refraction u. s. w.").

1. Fund. Astr.	60″.320
2. Tab. Reg.	.440
3. Tab. Pulk.	.268

4.	Fuss	.122
5.	Greenw. 1857-1865	.120
6.	Pulk. 1865	.209
7.	Greenw. 1877-1886	.192
8.	Pulk. 1885	.058
9.	München	.104

The first and second of these are determinations by BESSEL; the third by GYLDÉN; the fifth, by STONE; the sixth, by NYRÉN; the seventh, by NEWCOMB; the eighth, by NYRÉN; and the last, by BAUSCHINGER.

BAUSCHINGER gives weight zero to each of BESSEL'S determinations; to the first because there was considerable uncertainty in BRADLEY'S meteorological instruments; to the second, because of the uncertainty in reading the meridian-circle (read by vernier to one second). He gives equal weight to the last seven, and gets for a mean

$$\alpha = 60''.153$$

The *apparently* fine agreement of my value with this mean, however, is purely accidental, as can be seen from some further reductions of the observations which were made later. It was noticed that the value of $d\alpha$ derived from individual pairs of stars was a function of the zenith distance of the pair used. Upon plotting these values, using the zenith distance z for abscissa, and $d \log \alpha$ for ordinate, it was easily seen that these values varied quite uniformly with the zenith distance. Therefore, a term depending upon the zenith distance was introduced and the resulting equations solved by the method of least squares. This solution led to the conclusion that the so-called constant of refraction used in the Pulkowa tables needs not only a correction, but a correction for every zenith distance. In other words, the formula from which refractions are computed needs to be modified. Or the formula may be retained unaltered, and the desired agreement between observation and computation may be obtained by correcting the tables used (Pulkowa) not by a constant amount but by a variable one represented in magnitude by the expression

$$\Delta \log \alpha = 0.000101 \; [56^\circ \; 38'.8 - z]$$

where z is the zenith distance.

THE WATSON ASTEROIDS.

By Burt L. Newkirk.

(Read at the meeting of the Society held in Berkeley January 30, 1904.)

James C. Watson was born in the province of Ontario, Canada, January 28, 1838. He graduated at the University of Michigan in 1857, and became Professor of Astronomy and Director of the Observatory of that institution six years later. He was one of our most prominent astronomers, having written a book on theoretical astronomy which is still very widely used in the United States. He died in 1880, at the age of forty-two years. During the course of his scientific career he discovered twenty-two asteroids, and at his death left a sum of money as an endowment fund, the income from which should be used to pay for certain investigations and computations which it is necessary to make in order that these asteroids may not be lost to the scientific world.

Beside the well-known greater planets the Sun's system contains a host of very minute planets called asteroids. They revolve about the Sun in the space between the orbits of *Mars* and *Jupiter*. The first one of these to be discovered was found upon the first night of the nineteenth century, the night of January 1, 1801. This is the asteroid *Ceres,* and it is the brightest, and presumably the largest, of the group, having a diameter of 600 miles. Since the introduction of photographic methods in the search for these bodies, their discovery has been made comparatively easy, and something over five hundred of them have already been found, every year adding twenty or thirty to the list. At the time of Watson's death, in 1880, less than two hundred had been found. The smallest of these bodies are probably nothing more than great rocks, ten or fifteen miles in diameter. Smaller asteroids than these undoubtedly exist, but are so excessively faint as to elude discovery.

Of all the planets of the Sun's system these asteroids offer the greatest difficulties in the matter of the investigation of their orbits. We say, roughly speaking, that the planets move about the Sun in elliptical orbits; but, more accurately speaking, none of the bodies composing the Sun's system move in ellipses. According to NEWTON'S law of gravitation, every particle of matter attracts every other particle. If the Sun were attended by one planet only, this planet would move in an ellipse. but since each planet is attracted not only by the Sun, but also by all the other planets, its path is a curve of corresponding complexity. Since the Sun's attraction is generally by far the most powerful of all the forces acting upon any one planet, it is convenient to think of the actual orbit described by a planet as a "disturbed ellipse," as we express it. We picture to ourselves an ellipse which nearly coincides with the actual orbit, and in which the planet would move if the attractive forces of the other planets should at some particular instant cease to operate. The departure of the true orbit from this assumed ellipse, due to the disturbing action of the other planets is called the perturbation of the planet under consideration. The only reason for taking an ellipse as a starting-point in the discussion is one of convenience. A circle, which is a simpler curve from a mathematical point of view, might answer the purpose in some cases better than an ellipse, and for other purposes it is advantageous to take as a starting-point a curve of greater complexity. I refer to the "periplegmatic" curves used by GYLDÉN, which represent the path of the planet throughout a long period of years much better than any ellipse could, but seem to possess no advantages in tracing the planet's motion for a short period of time. It is a comparatively simple matter to compute an elliptic orbit, but to investigate the deviations from this orbit—i. e. the perturbations of a planet—is a task requiring in some cases a tremendous amount of labor and study.

The mathematical difficulties of the problem are such that no general method can be employed for computing the orbits of all the planets. Each planet must be treated with reference to the special difficulties which it presents, and this necessitates an intelligent and discriminating study of the various methods used in investigations of this nature, their advantages and their limitations.

The method employed in any particular case must not only be mathematically correct, but it must also be capable of yielding the desired results with the required degree of accuracy and with a minimum of numerical computation. The method of most general application is one developed by HANSEN, and modified by HILL, NEWCOMB, and others. Newer methods which possess special advantages in certain cases have been developed by GYLDÉN, BOHLIN, and BRENDEL. These latter methods are, however, comparatively untried, and it has been found necessary here in the asteroid work at Berkeley to revise BOHLIN'S method to some extent, before employing the formulæ given. Upon opening correspondence with BOHLIN, whose method has been used on some asteroids here, Professor LEUSCHNER found that BOHLIN himself had arrived at the same conclusion and was at work upon a revision of his theory.

In the case of the asteroids the problem presents special difficulties because of the proximity of *Jupiter*, which is the largest planet, and exerts a very powerful disturbing force. In most cases, in fact, unless a high degree of accuracy is required, the effect of all the other planets combined is a negligible quantity as compared with the perturbations produced by *Jupiter*. Difficult as the problem is, it is however absolutely necessary to compute the perturbations if we would keep the asteroids from retiring again into the oblivion from which their discoverers drew them. It is not possible to predict the motion of an asteroid ten or fifteen years in advance with sufficient accuracy to permit of its being found again at the end of that time without serious difficulty unless this work is done.

In the light of these remarks, Professor WATSON'S object in endowing the twenty-two asteroids discovered by himself will be clear. If their perturbations are not derived, his asteroids will be lost to the world in a few years, but, thanks to the fund he has bequeathed for this purpose, it will be possible to predict their motion for fifty or seventy-five years in advance with sufficient accuracy to enable astronomers of the future to find them again when they are wanted without serious difficulty. One of the twenty-two must be excepted from this statement. The asteroid *Aethra*, whose original path passed close to that of *Mars*, has suffered such violent perturbation that the form of its orbit has been greatly changed, and it has not been identified since, in spite of the diligent search which has been made for it. The tracing of the motion of this planet by means of a special mathematical discussion, which will be an exceedingly difficult matter, is to be undertaken by

Miss Hobe, who is now engaged with me upon the perturbations of the other asteroids, under the direction of Professor Leuschner.

Since Professor Watson's death, in 1880, the trustees have been trying to carry out the desire expressed in his will, by preparing tables by means of which the motion of these asteroids can be predicted for, say, fifty years in advance, with sufficient accuracy to permit of their being readily found. Up to two years and a half ago, when the work was undertaken by this department, considerable had been done, but little was ready for publication. Since that time the perturbations of ten planets have been computed here in Berkeley, and those of two more are nearing completion. Five others are to be treated by Bohlin's method, the work on these being already under way: the four remaining asteroids have been made the subject of investigation by other astronomers in Europe and America.

Perhaps the most important result of the investigations of the orbits of the Watson asteroids is the light thrown upon the whole subject of asteroid orbits and the methods best adapted to the various cases that arise. The treatment of twenty-two asteroids yields data which will be very valuable in the solution of one of the great problems which now confronts mathematical astronomy,—namely, that of providing tables by means of which the position of any one of the known asteroids may be found without excessive labor.

Before our tables for finding the planets in future years can be finished it will be necessary to compare the results of our investigations with observations. It is possible by this means greatly to improve the results of the numerical work. For this purpose the photographic telescope and Repsold measuring apparatus will be available. With the help of these instruments we shall be able to observe the positions of the asteroids, and a comparison of observations with theory will lead to a final improvement of the tables before publishing them.

The Watson trustees have, as may be imagined from the long time that has elapsed since Professor Watson's death without the completion of the task, had great difficulty in getting the work done satisfactorily. They have, however, been very well pleased with the progress made here by Drs. Craw-

FORD and ROSS, under the supervision of Professor LEUSCHNER, and have now turned the whole work over to the latter to be completed and prepared for publication. The work is being carried on under the auspices of the National Academy of Sciences, and the present Watson trustees are: Professor SIMON NEWCOMB (chairman), Professor LEWIS BOSS, and Professor W. L. ELKIN. It is their intention to have all the results published in due time. It has, however, seemed fitting upon this occasion to offer to those interested in the Berkeley Astronomical Department this brief statement of our connection with the undertaking.

THE PHOTOGRAPHIC EQUATORIAL OF THE STUDENTS' OBSERVATORY.

By ALLEN F. GILLIHAN.

(Read before the meeting of the Society, held in Berkeley, January 30, 1904.)

It has been demonstrated by Professors BARNARD, WOLF, and others, that lenses of the portrait type, and of large aperture, on account of their great light-grasping power, are very suitable for obtaining, with long exposures, photographs of very faint stars. Such a lens has been in the possession of the Students' Observatory for some years, but for lack of a suitable mounting, little work could be done with it. From time to time, however, it has been strapped to the tube of the 6-inch equatorial, together with its wooden camera, but as, until recently, the driving clock of this instrument did not perform well, and as there was no slow motion in hour-angle, this mounting was entirely unsuitable for photographic purposes. The need for a suitable mounting was thus greatly felt, particularly so in connection with the department's work on the Watson asteroids, it being the intention to verify by photographic observations their computed positions before tables for these asteroids are constructed.

Correspondence with various instrument-makers developed the fact that a mounting such as was desired could be constructed only at a greater loss of time and cost than seemed desirable. The department, therefore, decided to attempt the construction of a suitable equatorial mounting here in Berkeley, and after some study of various mountings the regular Fraunhofer model was selected.

In designing the instrument the special purpose for which it was to be used was kept constantly in mind, the object being to construct an instrument of the utmost efficiency for photographing with short-focus lenses, with a powerful and accurate driving-clock, efficient slow motion in hour-angle to control the clock, with all necessary adjustments to facilitate guiding in the dark, and with simplicity and solidity of mounting. It was also necessary to keep the cost at a minimum.

The design of our 6-inch equatorial being both simple and substantial, was used as a model, objectionable features being eliminated and necessary improvements added. One of the special features of the photographic equatorial is, that the frame has been made very compact and heavy, and in as few parts as possible. The clock has been put in a case with glass doors, situated between the equatorial head and the cast-iron column, where it will be protected from dust and moisture. The case needs to be opened only to regulate the pendulum or to oil the clock, but not to wind it. The starting and stopping mechanism is controlled from the outside of the case by means of a button on the north side of the pier. Considerable expense was saved by using commercial gear-wheels in the clock. The teeth of these wheels appear to be very evenly spaced, but the central hole in each wheel had to be recut, as every one was eccentric.

The governor is YOUNG's double pendulum, which is much used in modern instruments on account of its sensitiveness, even action, and freedom from variations due to changes in temperature or to moisture. An important feature in the clock is, that it requires about forty-five to fifty pounds' weight on the drum to make the governor revolve at the proper speed when it is not connected with the instrument; while with the governor removed and the clock connected with the instrument, it requires only about five or six pounds to drive the instrument; that is, the ratio of the weight required to drive the governor to the weight required to drive the instrument is about as seven or eight to one. When, therefore, an extra camera or other weight is added to the instrument, it will make very little, if any, difference in the speed of the governor. The clock is provided with maintaining power, and under the present arrangement will run for over three hours with one winding.

Another important part is the worm and worm-wheel, which were cut in the Mechanical Department of the University, the worm-wheel having 480 teeth, and the worm revolving once in three minutes. Mr. G. W. RITCHIE, in the *Astrophysical Journal* for November, 1901, in describing the photographic reflector constructed at the Yerkes Observatory, stated that after the instrument was assembled the worm and worm-wheel were ground together with emery flour and oil for a period of 200 hours, and afterwards polished. To this he ascribes the smooth running of the instrument. In our instrument the worm was connected by pulleys and belting directly with the driving-shaft in the workshop in such a way that when the shaft was revolving the worm-wheel, which under the influence of the driving-clock would revolve once in twenty-four hours, was made to revolve in forty-five seconds. The wheel and worm were ground together, using emery flour and oil, for nearly thirty-three hours, making over 2,600 revolutions of the worm-wheel, which at ordinary speed would be equal to about seven years' continuous running. The oil and emery were then removed, and the wheel and worm were polished, running at the same speed, using oil and rouge, for over four hours, which is equivalent to 340 turns, or nearly one year, of continuous running. In this way any irregularities were ground out, and the worm was firmly seated in the worm-wheel, where it is held in close contact by means of a strong adjustable steel spring.

The slow motion in hour-angle is introduced between the driving-clock and the worm. It is a differential gear or mouse control worked by an endless cord in the hand of the observer. Tangent-screw hour-angle slow motion brought to the eye-end of the instrument by gears is expensive, and besides has limited range; the observer is very liable to jar the instrument in moving the handle. None of these disadvantages prevail with the mouse control; while guiding the observer need not touch the instrument, except in case of a comet moving rapidly in declination. In this event, however, very accurate driving is not essential.

Clamp in hour-angle, clamp and slow motion in declination, are brought to the eye-end as in other instruments. Both slow motions are made particularly delicate, for use with a high-power eye-piece. Four feet six inches of the hour-angle slow-motion cord moves the instrument through one minute of time, and one turn of the declination slow-motion handle corresponds to four minutes in declination.

The declination-sleeve has been made unusually long, and with the circle partly counterbalances the telescope and cameras. The circles have white figures on black background, being easier to read in the dark than black figures on a white ground. The declination-circle is graduated to $30'$ and reads by verniers to $2'$. The hour-circle is graduated to 4^{m} and reads by verniers to 20^{s}. These graduations are fine enough for setting purposes.

A flat iron bed-plate 1 ft. x 2 ft. takes the place of the usual saddle on the end of the declination-axis to which the telescope is fastened. On it a wooden platform 2 ft. x 3 ft. is firmly fastened. The guiding telescope, a 3½-inch Mogey refractor, is fastened to one side of the under surface of this wooden platform, and a balance weight is fastened to the other side. This leaves the upper surface free for screwing on one or more cameras. This platform is a temporary expedient for the purpose of testing various cameras; later the cameras will be fastened directly to the bed-plate.

The polar-axis bearings are conical, and the weight is taken off the upper bearing by a pair of counter friction-wheels suspended in a frame-work which is pulled up by a strong adjustable steel spring. The end-thrust of the polar axis is taken up by an adjustable ball-bearing at the lower end. All those parts of the instrument that may wear or work loose are adjustable, so that lost motion may always be prevented. For example, in the declination slow motion provision is made for taking up lost motion in three directions, so that this very important adjustment can never wear loose.

A few words regarding the photographic lens: it is a C. C. Harrison portrait combination of about 5½ inches aperture and about 22 inches equivalent focus. The camera carries a 6½ x 8½ plate, but the field of view, where the star disks are quite sharp, is limited to about 10 centimeters square, or about 10° square. An exposure of about twenty minutes on a good night will give impressions of stars of about 11th or 12th magnitude and good measurable images of 10th magnitude stars. As an example of the work possible with this lens, on December 29, 1902, with the camera strapped on the 6-inch equatorial, an exposure was made for $1^h\ 13^m$ of the region around asteroid (385) 10.1 magnitude, and a distinct trail was found very near the computed position of the asteroid.

A description of the photographic equatorial would not be complete without mentioning those connected with its construction. The heavy castings and their patterns were made by the California School of Mechanical Arts; the heavy machine work is by the J. A. Gray Machine Co.; the composition castings are by the Eureka Foundry; and the circles were graduated by the A. Lietz Co.; all of San Francisco. All other parts of the instrument were constructed by Mr. VALDEMAR ARNTZEN, of the Department of Civil Engineering. He has done all of the finer instrumental work, and also helped in solving several knotty problems in the designing.

No work has been done as yet with this instrument; but it is hoped that it will be possible in the near future to present to the Society a satisfactory report of its work.

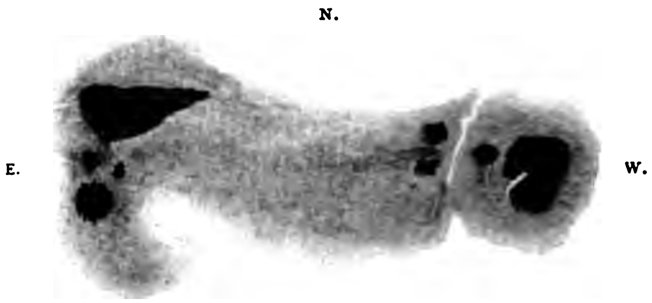
A FEW DETAILS OF THE TWELVE-YEAR SUN-SPOT CYCLE.

By ROSE O'HALLORAN.

Though regularity in the increase and decline of solar activity first led to a recognition of sun-spot periods, still each cycle of change has its individual traits, tendencies, and occasional discrepancies. The cause of periodicity being entirely unknown, such details are of interest, as they may be more than unimportant casualties. The following brief summary of observations from November 1, 1891, to November 1, 1903, contains some of the characteristics of the prolonged cycle that occurred between these dates. According to Professor WOLFER's revision of sun-spot data, a marked minimum took place early in 1890. This extreme stage of unspottedness did not recur until the summer of 1902; while the last maximum, which showed its approach towards the end of 1891, had its corresponding stage only in October of 1903, so that, dating the cycle either from the extremes of minima or from incoming maxima, its duration was beyond the average period of eleven and one tenth years.

As I used a Brashear refractor four inches in aperture, only very small faint spots were undiscernible in clear weather. When visiting the line of totality of the eclipse of 1900 an interruption of some length occurred, but it makes little change in the outline of decreased spottedness, as the minimum was far advanced. One aim of these observations has been to note the number of times that the photospheric whiteness of the disk has been noticeably invaded. A discolored area, whether stained by one spot or by many, is classed as one disturbance when the sprinkling does not extend beyond twenty-five degrees of the Sun's surface. which, being about the limit of the largest spots, gives some clew as to the probable range of a single eruption. This method, though giving a far less numerical result than if each fragment of a discoloration were counted. avoids including any spot more than once.

From November 1, 1891, to the same date of 1903, the Sun was observed and the results recorded on 2.982 days, and. according to the method adopted, 811 spotted areas were seen on the disk during that time. Two thirds of the disturbances occurred within the first five years. the remainder being distributed over the ensuing years with decreasing frequency until September, 1902, when a slight but distinct increase of activity set in. Of the entire number. about forty sufficiently conspicuous to be visible under favorable conditions without magnifying power may be classed as large; and formations which. from depth of hue combined with enormous extent. were distinctly visible to the world at large crossed the disk on four notable occasions. The first. one of the greatest on record. 150.000 miles in length and 75.000 in breadth. was fully inside the southeast limb on the 4th of February. 1892. and with many changes and divisions continued in view until the 17th. The second. when central in the southern hemisphere. on the 6th and 7th of August. 1893. was nearly 100.000 miles in length. and with much stability of color and form crossed the disk among a dozen smaller eruptions sprinkled over the spot zones. The third, with compact umbra and enormous penumbra, tinged the southerly tracts from the 2d to the 15th of September, 1898. In one respect it was the most remarkable spot of the cycle. The maximum climax was five years past, the minimum was approaching, when some irresistible counter force shattered the law of quietude over an area 140,000 miles in length. The same hemisphere was also the background of the interesting group of last October. With diversified phases, it lingered from the 5th to the 17th of the month, and, though unequal to the first and third in extent, it far surpassed any sun-storm within the previous five years.



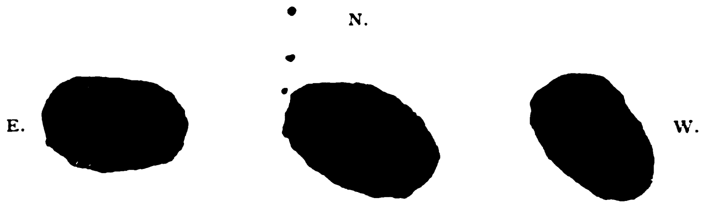
Great Sun-Spot, August 7, 1893.

There is good evidence that many of the large spots were of long duration, and came to view by rotation more than once, but change of form and of position renders complete identification impossible. As in the previous cycle, from 1879 to 1890. the northern zones were more quiescent on the whole than the southern, but the distribution was less unequal, being in the proportion of about seven to ten. This estimate was deduced from 567 disturbances distinctly beyond equatorial zones, as without accurate instruments for the measurement of heliographic latitude perspective effects are misleading at certain seasons.

During the years of maximum, spots frequently appeared in latitudes far from the equator, but from 1897 to 1901 more central zones were chiefly the scene of the diminishing activity, while later a scattering of forces was resumed, which is often a symptom of returning maxima.

In May, 1894, three fourths of the solar circumference was strewn with spots of average size from about twenty to thirty degrees apart; and lesser displays of streaminess were also noticeable three times in 1895, once in 1896, and again in 1898.

As M. FAYE, the French scientist, considers sun-spots to be vortical formations, a whirling tendency is a detail of interest, especially when contrary to the hands of a watch in the southern hemisphere of the Sun, and the reverse in the northern.



March 29th. April 1st. April 4th.

Cyclonic Sun-Spot, 1899.

Such cyclonic motions were detected in January, 1892, in April, 1899, and also less conspicuously on several other occasions.

On August 25, 1894, the disk was freer from discolorations than on any day when observed during the previous two years and ten months, which included 630 observations. From this time forward an unblemished photosphere was more frequently seen, and days, weeks, and finally months of undisturbed whiteness announced that maximum had gradually given place to minimum. Eighty-six days of unspottedness were distributed throughout 1901, and 147 days throughout 1902. In the latter year, from June 6th to September 11th, when an unspotted disk was viewed on 91 days, the extreme stage of minimum seems to have occurred. After a week of cloudy weather two spots appeared on the 19th of September, and thenceforth a slight increase of spottedness was evident until October, 1903, when the present maximum commenced.

Shadings in the granulated solar surface, often noticeable with a high power on clear days, have been ignored in this summary of observations.

SAN FRANCISCO, CAL.

THE SUPPORTING AND COUNTERWEIGHTING OF THE PRINCIPAL AXES OF LARGE TELESCOPES.*

By C. D. Perrine.

In a telescope whose moving parts weigh several tons it is desirable to reduce the friction in the bearings as much as possible. This is particularly true in the case of the polar axis, which must be driven by a clock at a very regular rate.

The practice has been to have the axis revolve in fixed boxes, usually lined with Babbitt metal, and to relieve the greater part of the pressure by a system of friction-wheels which are pressed upward against the axis, near the bearing, by suitable weights and levers. This is in effect transferring the pressure to smaller surfaces having slower motions. In some cases a ring of rolls has been used in connection with levers and weights. These systems have reduced the friction materially.

In designing the driving-clock of the new mounting for the Crossley reflector of the Lick Observatory I used a simple form of roller-bearing for the drum-shaft and the next two shafts in the train. This form of bearing was not adopted until after an experimental trial, which resulted most satisfactorily. The admirable performance of these bearings has suggested the suitability of this principle for the axes of large telescopes, particularly the polar axes.† Such bearings would do away with the necessity of any auxiliary system of counterweights, and I have reason to believe that, with proper construction, the friction would be less than with the best of the counterweighted systems. As to their accuracy and freedom from play, there should be no difficulty, judging from those already tried. These fit closely, there is no looseness whatever, and the shaft turns with perfect ease and smoothness.

The construction is simple. There is no frame to hold the rolls in fixed relative positions. The rolls are placed in the bearing and are kept from falling out by plates fastened to the body of the bearing. The rolls should fit snugly, but not so closely as to introduce appreciable friction between the elements of their surfaces which are in contact. The ends of the rolls should be beveled slightly, away from the center, leaving only a small surface or knob to come into contact with the plate. The rolls should be of steel, hardened and ground accurately round and to uniform diameters. The shaft should of course be of steel, accurately turned and ground. The bearing should be lined with a shell of steel to form the other rolling surface. although close-grained cast-iron makes a very good surface.

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* Read before Section A of the American Association for the Advancement of Science at the St. Louis meeting, December 28, 1903.

† It was not possible to adopt this system in the new telescope-mounting, as the heavy parts had already been constructed.

The dimensions of the shaft and rolls should be such that there will be not less than fifteen of the latter, thus always having several rolls which are taking the weight. There will then be less tendency for the rolls to jam or the shaft to settle between two of them. The latter condition would be fatal to the working of the system. If the rolls were long, it is probable that they would work more smoothly if cut into sections.

There is perhaps no more satisfactory way of taking the thrust of a large polar axis than that in common use—a balanced plate and one or two rings of balls.

When the parts which move in declination weigh not over four or five tons, the declination-axis performs very well with Babbitted bearings, the thrust being taken by steel shoulders and collars working against Babbitt. Such axes would, however, move much more easily with rolls, and balls to take the thrust. In large instruments a reduction of the friction of this axis is necessary.

The system of roller-bearings here suggested would be fully as efficient in the case of a large overhang of the polar axis as in the ordinary form of mounting.

If the polar axis is supported on two separate piers, the bearings are entirely independent of each other, and some means of aligning the bearings must be provided. It has usually been the custom in such cases to make the bearing in two parts: a lower section with a broad base, and the usual cap. By providing the lower half with screws for leveling and for lateral adjustment the necessary alignment can be secured. It is, however, an advantage to have the bearings self-aligning. This can be accomplished by making the lower half of the bearings in two parts which fit together on cylindrical surfaces, the axis of these cylindrical surfaces being at right angles to the polar axis and passing through the center of the bearing. Lugs and holding-bolts serve to keep the two portions together. This device allows the bearings to adjust themselves, in altitude, to the polar axis. The adjustment of the bearings to the axis in azimuth can be accomplished by having a stout pin on the under side of the lowest section of the bearing, which turns in the base-plate. Such a system would make the bearing a universal joint through small arcs, and wholly self-aligning. Bolts for holding the bearing to the pier should of course be provided.

The bearing at the lower end of the polar axis can be made to take the thrust and at the same time be wholly self-aligning. This may be done by extending the cylindrical portions upward around the end of the axis so as to contain the line of thrust.

When both ends of the axis are supported from the same base-casting, the bearings are usually fixed. Even in that case there would probably be some advantage in using self-aligning bearings.

While the subject of this paper properly belongs to a different Section of the Association, it is perhaps of special interest to astronomers.

MT. HAMILTON, CALIFORNIA, November 30, 1903.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1904.

By MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter,	May	7,	$3^h 50^m$ A.M.	Last Quarter,	June	5,	$9^h 53^m$ P.M.
New Moon,	"	15,	2 58 A.M.	New Moon,	"	13,	1 10 P.M.
First Quarter,	"	22,	2 19 A.M.	First Quarter,	"	20,	7 11 A.M.
Full Moon,	"	29,	12 55 A.M.	Full Moon,	"	27,	12 23 P.M.

The Sun reaches the solstice and summer begins on June 21st at about 1 P.M., Pacific time.

Mercury on May 1st is an evening star, setting about an hour and one half after sunset. It passed greatest east elonga-

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tion on April 21st, and is drawing nearer to the Sun, so that it can be seen for only a few days at the beginning of the month. It passes inferior conjunction on the morning of May 13th, becoming a morning star, and moves rapidly away from the Sun, reaching greatest west elongation on June 8th. Its distance from the Sun is then 23° 46′, but it is 9° south of the Sun, and therefore the interval between the rising of the planet and of the Sun is not as great as it is at some greatest elongations. However, during all except the last few days of the month *Mercury* rises an hour or more before the Sun, and may be seen in the morning twilight if weather conditions are favorable. It is in close conjunction with *Mars* on May 9th, 0° 21′ north, and with *Venus* on May 22d, 1° 53′ south, but both conjunctions occur when the planets are rather too near the Sun to be made out without a telescope.

Venus is still a morning star, but is gradually drawing too near the Sun to be conspicuous. On May 1st it rises only forty minutes before sunrise, on June 1st only thirty-two minutes before, and on June 30th only eleven minutes before. It will be a very difficult matter to see *Venus* without a telescope after June 1st. It will pass conjunction and become an evening star during the night of July 7-8th. *Venus* and *Mars* are in conjunction at about midnight on June 18th, the former being 0° 35′ north, but, like the *Mercury* conjunctions, the planets are too near the Sun for easy view.

Mars is too near the Sun throughout the two-months period for naked-eye observations. At the beginning of May it is an evening star, setting only a little more than a half-hour after sunset. It passes conjunction with the Sun on May 30th and becomes a morning star. At the end of June it rises about forty minutes before sunrise. It will, however, scarcely be possible for it to be seen without a telescope, as it is at the same time at its maximum distance from the Earth for this revolution (238,000,000 miles), and consequently at its least brightness. For a year more, until it comes to its next opposition in 1905, it will gradually grow brighter, but it will not be at all conspicuous during the rest of 1904.

Jupiter passed conjunction with the Sun at the end of March, and by May 1st rises about an hour before sunrise. The interval increases, so that at the end of June it rises half an hour after midnight. Its brightness is so great that it may be made out at the beginning of the two-months period. During May and June it moves 11° eastward and 4° northward in the eastern part of the constellation *Pisces,* rather a barren region of the sky.

Saturn is gradually moving around to a more convenient position for observation. It rises a little before 2 A.M. on May 1st, at about midnight on June 1st, and before 10 P.M. on June 30th. It is in the constellation *Capricorn,* and moves about 1° eastward until June 1st, and then begins to retrograde, reaching a position at the end of June almost the same as it had on May 1st.

Uranus is now getting into position for evening observation, rising before 11 P.M. on May 1st and at about half-past 6 on June 30th. It is in opposition on June 19th, and is then above the horizon throughout the night. It retrogrades or moves westward about 2°, and is in the western part of *Sagittarius,* a little north and west of the group known as "the milk-dipper."

Neptune is in the western sky in the evening, in the constellation *Gemini.* It reaches conjunction with the Sun on June 27th.

VARIABLE STARS.

By Rose O'Halloran.

V Cassiopeiæ.

1903. Eleven observations, distributed between the 17th of August and the 14th of September, showed that in a 4-inch lens this variable was on the verge of invisibility, which is generally the stage of 12th magnitude. Fainter stars are undiscernible except on very clear, calm nights. September 16—Much more distinct. October 12—Between 9th and 10th magnitude, and distinctly brighter than the star just adjacent to it.

Y Cassiopeiæ.

The last maximum of this star was observed as follows:—
1903. August 27 — Scarcely of 11th magnitude, but distinctly seen below *b*, classed as 10.2. August 31, September 2, 8, 9—Ditto. September 13—Nearly equal to *b*. September

16—Fully equal to *b*. September 29—About 9.7; brighter than *b;* equal to *m* and *n*. October 28—Brighter than *b* or *d;* equal to *m* and *n*. November 6—Equal to *b*.

W Cassiopeiæ.

1903. June 24, 26, 29, 30; July 1, 2, 3, 6, 13, 19—About 10th magnitude. July 23—Declined to 10.3 magnitude. July 31—10.6 magnitude. August 16, 23—11th magnitude. August 29, September 2—11.3 magnitude. September 9, 14—Not discernible in haze. September 16—12th magnitude. September 29, October 18, November 6—Invisible.

In the *Companion to the Observatory* the minimum was predicted for October 18th. On this occasion it was probably fainter than 12th magnitude.

W Lyræ.

The last maximum occurred more than a month in advance of the predicted date, October 30th, as follows:—

1903. July 6—Not visible with high power in clear moonlight. July 11—Scarcely as bright as 12th magnitude, but distinct in high power. July 24, 25—Of 11.5 magnitude; fully equal to *t*. August 2, 5—Equal to *p*, of 9.4 magnitude. August 22—Of 8.7 magnitude; between *c* and *a*. September 6—Of 8.1 magnitude; brighter than *a*, equal to *n*. September 23—About two tenths brighter than *n*. October 5—In moonlight *W*, *a*, and *n* seem equal. October 13—The variable seems two tenths dimmer than *n*. October 18—Scarcely of 9th magnitude; between *a* and *p*, but nearer to latter. November 1—Equal to *p*. December 23—Scarcely of 12th magnitude.

1904. January 5—Not visible; morning clear. January 20—Ditto; probably less than 12th magnitude.

R Cygni.

1903. From June 25th to August 29th *R Cygni* was looked for in vain, but on October 18th was seen to be about 8.5 magnitude. November 1—Of 9th magnitude.

S S Cygni.

1903. Two maxima of *S S Cygni* were observed between July 23d and September 14th. July 23, 9.25 P.M.—Brighter than *a* or *c;* less than *b*. July 24, 9 P.M.—Nearer to *b*. July 25, 9.15 P.M.—Between *c* and *b;* nearer to *c*. July 30, 8.40 P.M.—Nearly equal to *b;* much brighter than *c;* night dim.

August 1, 8.40 P.M.—Not so near *b*, but brighter than *c*. August 2, 8.35 P.M.—Decreased, but still brighter than *c*. August 5, 8.30 P.M.—Less than *b*, *c*, or *a*, but brighter than *d*. August 16, 17, 23, 29, 31; September 2, 8—No longer identifiable among the stars of 12th magnitude near its place. September 9, 7.45 P.M.—Less than *b*; equal to *a* and *c*, which look alike to-night. September 13, 8 P.M.—Two tenths brighter than *a*. September 14, 7.50 P.M.—Still brighter than *a* or *c*. This constellation was lost to view after this date.

X Aquilæ.

1903. From June 25th to November 1st this variable was looked for on twenty-four clear evenings, but the faintest glimmer was undiscernible within some minutes of the place it occupies when visible. August 17th, the date of predicted minimum, was included. It was probably fainter than 12th magnitude.

R Tauri.

1903. December 8—Of 12th magnitude. December 22—11.5 magnitude. December 25, 26—10.5 magnitude.

1904. January 4—About 8.5 magnitude. January 6—Of fully 8th magnitude. January 11—About 7.7 magnitude. January 14—Seems slightly decreased. January 17—Of 8th magnitude. January 20—Rather brighter than 8th magnitude. January 22—Slightly decreased. January 23—Further decreased; scarcely of 8th magnitude. The previous maximum occurred in March, 1903.

(FORTY-SIXTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to M. BORRELLY, astronomer, Marseilles, France, for his discovery of an unexpected comet on June 21, 1903.

The Committee on the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
WM. M. PIERSON.

REPORTS OF OBSERVATORIES.

Manuscript intended for this department should be sent to FRANK SCHLESINGER, Yerkes Observatory, Williams Bay, Wis.

NAVAL OBSERVATORY, WASHINGTON, D. C.

During the year 1903 the following changes have taken place in the personnel:—

Mr. T. I. King, assistant astronomer, was transferred to the Nautical Almanac Department December 1st, at which date Mr. J. C. Hammond was promoted to fill the vacancy thus caused.

The instruments have been used as follows:—

The 6-inch transit-circle was devoted to the routine observations of the Sun, Moon, and planets up to September 4th, when the work was transferred to the 9-inch transit-circle. thus permitting the consideration of certain changes and additions to the instrument.

The 9-inch transit-circle, after the completion of extensive repairs and improvements, was put into commission September 3, 1903, and has since been used for the fundamental determination of the Right Ascension and Declination of the Sun, Moon, planets, and the stars of Newcomb's Fundamental Catalogue, Gill's Zodiacal Catalogue, and the Zodiacal Catalogue of the U. S. Nautical Almanac Office, now in press.

A new clock by Riefler, of Munich, in an air-tight glass case, with nickel-steel pendulum and electrical winding, was installed September 1st, and has been used since that date as the standard sidereal clock.

The prime vertical transit-instrument has been devoted to continuing observations for the determination of aberration, nutation, and variation of latitude and to the determination of the declinations of 390 miscellaneous stars.

The altazimuth instrument has been devoted to a determination of the latitude of the observatory and the declinations of 350 standard stars.

Photographs of the Sun have been obtained with the photoheliograph on every clear day.

The equatorials have been devoted to measurements of the diameters of the planets, and to the observations of the satellites, asteroids, comets, and occultations. Photography has been used in detecting the location of most of the asteroids which have been observed.

During the year 1903 the following volumes have been published: Volume III, *Publications of the U. S. Naval Observatory*, Second Series, containing observations of *Eros* and the reference-stars, observations of zodiacal stars and prime vertical observations 1882-1884; Volume V, *Meteorological Observations and Results, 1893–1902.* Volume IV is now in press.

Good progress has been made on the formation of the Catalogue of the Astronomische Gesellschaft Zone, — 13° 50′ to — 18° 10′, as well as on the cataloguing of the Washington zones 1846–1852.

The practical naval features of the observatory work are seen in the regular publications of the American Ephemeris and Nautical Almanac, and the purchase, trial, and issue to the naval service of chronometers, watches, sextants, telemeters, binoculars, surveying and photographic outfits, and all navigational instruments, except compasses. The time-service maintained in connection with the chronometer service sends out daily, except Sundays and holidays, telegraphic noon-signals that reach all points in the country, correcting some 40,000 clocks, and dropping sixteen time-balls.

The following articles by members of the Observatory staff have appeared during the year 1903:—

Elements and Ephemeris of Comet *a* 1903 (GIACOBINI), by H. R. MORGAN and ELEANOR A. LAMSON (*A. J.* 530 and *A. J.* 531-532).

Observations of Heliometer Comparison-Stars, by M. UPDEGRAFF and J. C. HAMMOND; Observations of Minor Planets, by J. C. HAMMOND; Observations of Comet *b* 1902 (PERRINE), by C. W. FREDERICK and W. W. DINWIDDIE (*A. J.* 533).

Observations of the Declinations of *Vesta*, by GEORGE A. HILL: Observations of the Right Ascensions of *Vesta*, by EVERETT I. YOWELL (*A. J.* 534).

Observations of Comet 1900 II, by GEORGE K. LAWTON (*A. J.* 535).

Observations of Comet *a* 1903 (GIACOBINI), by C. W.

FREDERICK; Observations of TURNER'S *Nova* (2387 *Geminorum*), by C. W. FREDERICK; Photographic Observations of the Minor Planet (60) *Echo,* by G. H. PETERS; Photographic Observations of Minor Planets, by G. H. PETERS (*A. J.* 537-538).

Observations of Minor Planets, by J. C. HAMMOND (*A. J.* 540-541).

Observations of the Satellite of *Neptune* and Comet *d* 1902 (GIACOBINI), by W. W. DINWIDDIE; Observations of Minor Planets, by J. C. HAMMOND; Observations of Comet *b* 1902 (PERRINE), by C. W. FREDERICK (*A. J.* 542-543).

Observations of BROOKS'S Comet 1889 V, by C. W. FREDERICK; Observations of Minor Planets, by J. C. HAMMOND (*A. J.* 547).

Observations of Comets and Minor Planets, by T. I. KING; The Instrumental Constants in Equatorial Work, by C. W. FREDERICK (*A. J.* 552).

Chronometer-Rates, by Lieut.-Commander E. E. HAYDEN (*Proceedings Naval Institute,* Vol. 29, No. 3).

The Pivots of the 9-inch Transit-Circle of the Naval Observatory, by W. S. EICHELBERGER (*Astron. and Astroph. Soc.,* December, 1903).

C. M. CHESTER, *Rear Admiral, U. S. N.,*
Superintendent Naval Observatory.

KIRKWOOD OBSERVATORY, BLOOMINGTON, IND.

As this observatory is a part of Indiana University, it seems necessary at present that the major part of the time and energy of the corps of instructors be devoted to teaching. This affects in a serious manner the quantity, certainly, and perhaps the quality, of research work done here. However, at least the first half of every clear night is devoted to work with the telescopes. A part of this time is used by students more or less advanced, whose work, though done seriously, is in the main that of amateurs.

During the past two years we have measured about three hundred pairs of double stars, which have been selected from those noted as double by observers while making the A. G. catalogues, and which have not been hitherto measured. The measures of two of these lists have already been published, and two other lists are now in manuscript. The measures were made with the 12-inch refractor to which is attached a micrometer by WARNER & SWASEY. With the same instrument we obtained a large number of positions of Comet *d* 1902 and Comet *a* 1903.

A mounting for a 15-inch reflector, the mirror of which was kindly loaned us by Mr. O. L. PETITDIDIER, of Chicago, has just been completed by the department. With this instrument a series of photographs of nebulæ and star-clusters has been made. With a portrait-lens of five inches aperture and with a small "tintype" lens a fairly complete series of photographs of BORRELLY'S Comet was obtained. Using a color-screen, we have succeeded in making with the refractor quite excellent photographs of the Moon.

JOHN A. MILLER, *Director.*

CHAMBERLIN OBSERVATORY, DENVER, COLO.

During the year 1903 only comet observations were made, the time of the director of the observatory being largely consumed by administrative work in connection with the University of Denver. H. A. HOWE, *Director.*

THE ASTROPHYSICAL OBSERVATORY OF THE SMITHSONIAN INSTITUTION, WASHINGTON, D. C.

Bolographic studies of the spectrum of the Sun and the provision of a large horizontal telescope to be used for studies of special portions of the solar radiation have been the distinguishing features of the work of the Astrophysical Observatory during the past year. Results of uncommon interest have been reached in the bolographic work of the past twelve months, and especially in the studies of the absorption of the solar rays by our atmosphere.

Briefly this has shown that the Earth's atmosphere, so far as it can be observed here, has been more opaque than usual within the present calendar year, so much so as to reduce the direct radiation of the Sun at the Earth's surface by about ten per cent, on the average, throughout the whole visible and infra-red spectrum, and by more than double this amount in the blue and violet portions of the spectrum. This alteration of the transparency of the air has not, however, been confined to the region of Washington.

Another interesting observation is that determinations of the rate of solar radiation outside the Earth's atmosphere might appear to indicate that there has been a decrease of the solar radiation itself since March 26, 1903; but I refer to this with hesitation, as I have elsewhere observed that it is scarcely possible to be certain of the accuracy of results of this sort when based on observations near sea-level. The value of a solar observatory at a high altitude, to which I referred last year, can hardly be overestimated.

A new determination of the temperature of the Sun, based on the distribution of the solar radiation in the spectrum, has yielded a result of 5,920° of the centigrade scale above absolute zero.

For the purpose of the special study of the nature of sun-spots, the absorption of the solar gaseous envelope, and for other observations requiring a large solar image an equipment including a horizontal reflecting telescope of 140-foot focus and 20-inch aperture and a cœlostat of improved construction to furnish at all times a 20-inch horizontal northerly directed solar beam has been provided. The form of cœlostat employed seems so well suited to solar work that this large instrument will be exhibited by the observatory at the Louisiana Purchase Exposition in 1904. Provision has been made in connection with the long-focus telescope to churn the air traversed by the beam from the cœlostat to the focal image after the manner described in my last year's report. It is hoped that this installation will have yielded results of interest before another year.

On the whole, the work of the Astrophysical Observatory during the past year has been quite as productive of results of interest as during any former year of its existence, especially in showing a notable variation of atmospheric transparency which is likely to have affected climate and the growth of vegetation over a considerable part of the Earth's surface, and in the studies of atmospheric absorption and those relating to the solar constant, to which I have referred, there seems renewed promise of progress toward the goal "foretelling by such means those remoter changes of weather which affect harvests," which is one of the great aims had in view in the foundation of the observatory.

S. P. LANGLEY,
Secretary of the Smithsonian Institution.

CINCINNATI OBSERVATORY, CINCINNATI, OHIO.

The work of this observatory during 1903 has been along the same lines as in the year previous. Observations for the variation of latitude were carried on with as great regularity as the weather would permit, 1,490 pairs having been obtained. The reobservation of the stars of PIAZZI's catalogue north of the equator with the meridian-circle was practically completed. It is hoped during the current year to publish the results.

Last summer the 11-inch equatorial, originally purchased by Professor MITCHEL, was dismounted. For nearly thirty years it stood on Mount Adams, a high prominence overlooking the city, and named in honor of JOHN QUINCY ADAMS, who delivered the oration at the laying of the corner-stone of the Cincinnati Observatory. For thirty years more the telescope has stood upon Mount Lookout, six miles northeast of the city. It is hoped soon to remount this historic instrument, the oldest of any considerable size in the Western Continent.

In the mean time the observatory has purchased of the Alvan Clark Corporation a new 16-inch equatorial, which will be installed early in the year. It is then expected to take up some lines of extra-meridian work.

J. G. PORTER, *Director.*

HARVARD COLLEGE OBSERVATORY, CAMBRIDGE, MASS.

East Equatorial.—Nearly all of the observations with this instrument have been made by Professor O. C. WENDELL, and have been of the same general character as in previous years. The errors of observation have an average value of three or four hundredths of a magnitude. Deviations of a tenth of a magnitude generally indicate real changes in the star measured. The effect of color also seems less troublesome than with visual observations. About two thousand measures have been made of stars suspected of variability by other observers. An attempt is made to measure, every year, all stars which vary more than half a magnitude an hour, on three nights when increasing in light, and on three when decreasing in light. About six thousand measures have been made of such objects. Seven hundred measures have also been made with a second photometer adapted to the comparison of stars too near together to be measured with the first instrument. The same instrument has been used in the photometric measurement of *Jupiter's* satellites while undergoing eclipse. Observations of variable stars of long period throughout their changes, and the reduction of the results to the scale of the meridian photometer have been continued.

Similar observations of variables and comparison-stars have been made with the *West Equatorial*. With it 1,724 estimates of variables and 399 of comparison-stars have been made by Miss CANNON. Three thousand three hundred and ninety-five estimates of variables, and 323 estimates of comparison-stars have been made by Mr. CAMPBELL with the naked eye, field-glass, and a 5-inch portable telescope. Some estimates of faint variables and photometric measurements of double stars were also made by Mr. CAMPBELL during the month of August, with the *East Equatorial*.

Meridian Circle.—The only important work of this instrument during the year has been the determination of clock-error. All the columns of the catalogue of stars belonging to the zone — 9° 50′ to — 14° 10′ are now provisionally complete, except that current numbers are not yet assigned to the stars. The work of re-computing particular observations, in cases of large discrepancy, is also very nearly finished.

12-inch Meridian Photometer.—The principal work has been the completion of observations undertaken in previous years, and the measurement of all the Durchmusterung stars in zones 10′ wide, north of Declinations — 5° and — 15°. A beginning has been made of the observations of stars in similar zones south of + 5°, + 15°, and + 25°. This work will supplement that already completed at Declinations — 20°, — 10°, 0°, + 10°, etc. Measures have also been made of sequences of stars from the eighth to the thirteenth magnitude, in twenty-three coarse clusters, to determine the absolute magnitudes of the components of these objects. By interposing a shade-glass so as to reduce the light of the star, any star however bright could be measured. Another modification of the instrument permitted surfaces to be measured.

Henry Draper Memorial.—Eight eclipses of *Jupiter's* satellites, and five occultations, have been successfully photographed with the 11-inch Draper telescope. Four variable stars have been found by Mrs. FLEMING, and one by Miss BRESLIN, from the examination of the Draper photographs. Among other photometric investigations of plates, it was found that a reduction of temperature from 70° to 0° F. increased the sensitiveness of plates by about half a magnitude. Photographic charts have been made here of the regions of asteroids which have not been observed elsewhere during the last three years. Several asteroids have thus been found, but owing to the faintness of the greater portion of these objects the 8-inch Draper telescope, which was the instrument employed, is hardly large enough for this work.

Boyden Department (Arequipa).—Measures have been made on 21 nights, with the meridian photometer, in extending to the South Pole the system of bright standard stars, one in each ten degrees square. Many measures were made with the Rumford photometer attached to the 13-inch Boyden telescope. Notwithstanding its faintness, the variations in the light of *Eros* have thus been measured by Professor BAILEY from March 30th to August 19th. Excellent curves have been obtained which show a variation in the range from about half a magnitude to a magnitude. Observations of fifty southern variables have been made, besides a careful study of their comparison-stars.

Bruce Photographic Telescope.—The number of photographs taken with the Bruce photographic telescope was 413. Although these plates are difficult to handle and liable to be broken, owing to their size, which is 14 by 17 inches, yet they are proving extremely useful, since by their aid stars may be studied which are much too faint to be photographed with our other instruments. The scale also permits positions to be determined much more accurately than with smaller instruments. Forty-two of these plates had exposures of one hour, and showed the spectra of the stars; the remainder were chart-plates, of which 17 had exposures of four to five hours, 66 of one hour, 166 of ten minutes; 87 were of the planet *Eros*, and 35 were miscellaneous. Mr. Frost, from an examination of 18 photographs, found 37 nebulæ not contained in Dreyer's catalogue. On one plate he counted 10,926 stars in one square degree.

Miscellaneous.—The reduction of the observations made by the late Professor Rogers with the meridian-circle, during the years 1879 to 1883, is being continued by Miss Bond. Mrs. Fleming has not been able for some time to continue the classification of spectra for the Southern Draper Catalogue. Arrangements have now been made so that she is doing this work at home in the evening. A stereocomparator has been constructed and gives satisfactory results. The Revised Harvard Photometry, containing about nine thousand stars, is now approaching completion. All stars in any part of the sky and of the magnitude 6.5 and brighter in any of our photometric catalogues are included. The anonymous gift of 1902 has been of the greatest service; it will provide two reflectors of twenty-five inches aperture, one for use on the northern and the other on the southern stars, and has given us a fire-proof wing to the building already used for storing and studying the photographs. The cost of the entire building and wing was only about $20,000, and two similar buildings would provide for a much needed new library for the observatory, computing-rooms, photographic laboratory, and a workshop.

Edward C. Pickering, *Director.*

THE WASHBURN OBSERVATORY, MADISON, WIS.

During the year 1903 the 40^{cm} equatorial telescope was employed by the Director in the following series of observations: (*a*) Micrometric observations for the determination of the parallax and proper motion of *Nova Persei*. This series, commenced immediately after the appearance of the *Nova*, will be continued at epochs of maximum and minimum parallactic effect so long as is feasible. (*b*) Micrometric observations of a selected list of binary stars known to be in relatively rapid motion. This work is in continuation of the observations contained in *Publications* of the Washburn Observatory (Vol. X). (*c*) The remeasurement of a list of wide double stars first observed a half-century since by the Struves. (*d*) Experiments to determine the adaptability of the telescope to celestial photography as a substitute for the micrometer.

The amount of work accomplished along these several lines has been considerably restricted by unfavorable atmospheric conditions, and in even greater measure by a large increase in the purely academic duties of the Director. Although no clerical assistance is available in connection with this work, the reductions of all observations have been completely made, and the observations of the binary stars are ready for publication. The observations of *Nova Persei,* while individually reduced, still require a discussion that can be given only when the series is complete.

The observations above noted under the rubric (*c*) were undertaken with a view to the determination of the proper motions of faint stars (8 to 12 magnitude), and the observing list is intended to include all stars of this character that have been compared by the STRUVES with bright stars of known proper motion. For a provisional account of the results already obtained, together with some discussion of their bearing upon current theories of the constitution of the stellar system, reference may be made to the *Astronomical Journal,* No. 558.

The meridian-circle of 12.2$^{\text{cm}}$ aperture was employed during the year 1903 by Mr. A. S. FLINT in observations for the determination of stellar parallax. These observations, beginning July 15, 1898, constitute a second series substantially similar to the first series of parallax determinations, contained in *Publications* of the Washburn Observatory (Vol. XI), save that in their conduct a Repsold transit-micrometer has been employed. The reader may consult the *Astronomical Journal,* No. 470, for an account of the observer's earlier experience with this micrometer and with the peculiar system of slat screens employed for diminishing the apparent magnitudes of the stars observed. The result of five years' additional experience is on the whole favorable to the apparatus, when employed, as is here done, with close parallel threads, between which the star's image is held during transit. After some experimentation the observer has adopted 10″ as approximately the most convenient distance between these threads.

The observing list of stars whose parallaxes are to be determined is made up as follows:—

Stars brighter than magnitude 1.5	1
Stars between magnitudes 1.5 and 2.5, inclusive	41
Stars between magnitudes 2.6 and 3.1, inclusive	26
Fainter stars of large proper motion	36
Binary stars	18
Miscellaneous stars	2
Total	124

It was the original intent to include in this list all stars between the magnitudes 1.5 and 2.5 that were within the reach of the instrument, and the number 41, above given, represents approximately two thirds of all stars of this class in the entire sky.

Observations of 66 stars of the foregoing list are now completed, with an average of 73.4 observations per star, including in most cases two comparison-stars for each star whose parallax is to be determined. Early in the progress of the work preliminary solutions were made in the case of six parallax stars, having an average of 53 observations per star, and from these it appears that the average probable error of a parallax thus determined is $\pm 0''.032$. The individual parallaxes thus determined were $+0''.01$, $+0''.04$. $+0''.05$, $+0''.26$, $-0''.02$ $-0''.01$.

Through the courtesy of the trustees of the Gould Fund of the National Academy of Sciences a grant of $400 has become available during the past year in aid of the reduction of these observations, and has considerably facilitated the work. The present state of the reductions is represented by the statement that, for the observations already made, approximately one half of the computing required to produce the absolute terms of the resulting observation equations is completed.

The parallax observations being in an advanced state, Mr. FLINT undertook, in October, 1903, and is now actively carrying on, the determination of the positions of a list of stars observed by the Director as comparison-stars in the work above designated (*c*). These are for the most part stars of moderate brightness, for the determination of whose proper motions modern observations are greatly needed.

Aside from the current determination of time, the transit-instrument and the small equatorial telescope of the observatory have been used only for purposes of instruction.

March 10, 1904. GEORGE C. COMSTOCK, *Director.*

INTERNATIONAL LATITUDE STATION, UKIAH, CAL.

The programme of the International Geodetic Association for observing variations of latitude was continued throughout 1903 without modification or interruption. Dr. SCHLESINGER'S connection with the station ceased on April 30th, and mine began on February 1st. Very good observing weather prevailed during nearly the entire year. The longest intervals without observations were nine nights in January, and again nine nights in December. December, however, yielded a unique record—sixteen complete (no incomplete) nights' work. Between November 29 and January 21, 1904, an unbroken record of twenty-eight complete nights was obtained. The total number of pairs observed was 2,655, which exceeds by 552 pairs the best previous record. The distribution by months is as follows:—

		Pairs.			Pairs.
1903.	January	155	1903.	July	209
	February	257		August	222
	March	161		September	200
	April	309		October	238
	May	261		November	172
	June	215		December	256

During the three months that Dr. SCHLESINGER and I observed together the nights were about equally divided between us, the plan being to determine the personal difference between the two observers. For this purpose 650 pairs were obtained, and a preliminary reduction of these gives a difference between results of the two observers of but 0".01, $\phi_S - \phi_T = +0''.01 \pm 0''.01$.

SIDNEY D. TOWNLEY.

VASSAR COLLEGE OBSERVATORY, POUGHKEEPSIE, N. Y.

During the past year the observatory of Vassar College has been occupied with the reduction of photographic plates covering the region about the North Pole. With the grant from the Carnegie Institution, two computers were engaged, who are still employed, and during the summer months the number was increased by two, one of whom had had considerable experience in such computation.

The reduction of the separate plates and their interadjustment have been completed, and the final catalogue is nearly ready. There remains still the determination of the proper motions, for which a large amount of material has already been collected. Of the stars on the plates, 31 are found in SCHWERD, 165 in CARRINGTON, 78 in the observations of FABRITIUS at Kiev, and 60 in the Greenwich observations for 1899 and 1900. Scattering observations are found in a number of other catalogues. With but few exceptions, the proper motions of these stars have never been determined.

During the past year a photometer, with a photographic wedge after the Harvard pattern, has been added to the equipment of the observatory, and has been used by Professor WHITNEY for observing variable stars.

The regular work of observing asteroids and comets has been omitted this year, since the computing force has been exclusively occupied with the plate-work.

The instruction which forms the principal work of the observatory force has continued as heretofore.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

DEFINITIVE ORBIT OF THE SPECTROSCOPIC BINARY ι *PEGASI*.†

This binary was discovered by Director CAMPBELL and announced by him in the *Astrophysical Journal* for May, 1899. The spectrum is of Type F, with fairly good lines. The determination of the orbit is made to depend upon forty-three plates, comprising all the plates of this star which have been taken with the Mills spectrograph, with the exception of a few of poor focus or insufficient exposure, which have been rejected. The formulæ and methods used are those of LEHMANN-FILHÉS [*A. N.* 3242], with the addition of a sixth unknown for the change in the assumed velocity of the system.

The preliminary orbit adopted as the basis of the solution is as follows:—

PRELIMINARY ELEMENTS.

Velocity of system $= -3.91^{\text{km}}$

$T = 1899$ June 15.515

$= $ Julian Day 2414821.515

$e = 0.0205$

$\omega = 272^\circ.732$

$\log \mu = 9.78864$

$\log \kappa = 1.67574$

Period $= 10^{\text{d}}.2132$

A second solution was found to be necessary, inasmuch as the agreement between the ephemeris from the first solution and substitution of the values of the unknowns in the equations of condition was not sufficiently close, due to omitted terms of the second order in the differential coefficients. The values of

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[*] Lick Astronomical Department of the University of California.

[†] Abstract of the *L. O. Bulletin*, No. 53.

the unknowns derived from the second solution, with their probable errors, are as follows:—

VALUES OF UNKNOWNS, SECOND SOLUTION.

$\delta V = -0.09 \quad \pm 0.11^{\text{km}}$

$\delta T = -0.200 \quad \pm 0.352$ days

$\delta \mu = +0.00000007 \quad \pm 0.00000407$

$\delta \kappa = +0.0327 \quad \pm 0.1523$

$\delta \omega = -0.1230 \quad \pm 0.0240$ radians

$\delta e = -0.00008 \quad \pm 0.0040$

FINAL ELEMENTS.

$V = -4.12 \quad \pm 0.11^{\text{km}}$

$T =$ 1899 June 14.966 ± 0.352 days

$= \text{J. D. } 2414820.966$

$e = 0.0085 \quad \pm 0.0040$

$\omega = 251^\circ.807 \quad \pm 1^\circ.373$

$\log \kappa = 1.68117 \quad \pm 0.00014$

$\log \mu = 9.7890216 \quad \pm 0.0000029$

$\mu = 35^\circ.2488 \quad \pm 0^\circ.0002$

Period $= 10.21312 \quad \pm 0.00006$ days

$a \sin i = 6{,}740{,}000^{\text{km}}$

The sum of the squares of the weighted residuals has been reduced from 51.14 to 26.25.

The probable error of a single plate as derived from this solution is $\pm 0.56^{\text{km}}$. The relatively large probable errors in the values of T and ω arise from the fact that the orbit is nearly a circle, the eccentricity being only $+0.0085$. On the other hand, inasmuch as the observations cover two hundred and nineteen complete revolutions of the star, the period is determined with considerable accuracy. The largest residual is -2.14^{km}; the range of velocity is from $+43.7^{\text{km}}$ to -52.1^{km} per second.

HEBER D. CURTIS.

March, 1804.

RECENT MEASURES OF ε *HYDRÆ*, AB.

Measures on three nights of SCHIAPARELLI's rapid binary system, ε *Hydræ*, AB, give the following mean result:—

1904.047 $\quad 147^\circ.2 \quad 0''.25$.

The position for this epoch derived from my preliminary elements* is $150^\circ.9$, $0''.25$, leaving the residuals (O—C).

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* See these *Publications*, Vol. XV, p. 84, and *L. O. Bulletin*, No. 36.

— 3°.7 ± 0″.00. These correspond to a displacement of the companion-star of less than 0″.02 in arc.

R. G. AITKEN.

March, 1904.

A NEW COMPANION TO Σ 1506, AND A NEW NAKED-EYE DOUBLE STAR.

Two of the new double stars recently discovered with the 36-inch telescope are of sufficient interest to be noted at this time. One is a naked-eye star in *Monoceros*, whose position for 1900.0 is R. A. $6^h\ 10^m\ 40^s$; Decl. —9° 0′; the other is the companion to the wide pair Σ 1506, which I find to be a close double. The results of my measures of these stars are:—

Star.	Date.	Angle.	Distance.	Magnitudes.	Nights.
1	1904.05	158°.2	0″.23	6.6 – 6.6	4
2	1904.08	55 .5	0 .20	10.0 – 10.0	1 BC (new)
	.08	216 .1	11 .12	7.3 – 9.5	1 A and BC (= Σ1506)

March, 1904.

R. G. AITKEN.

HONORS FOR DIRECTOR CAMPBELL.

Professor W. W. CAMPBELL has been elected a Foreign Member of the Societa degli Spettroscopisti Italiani. This society consists of thirty Italian members and thirty foreigners. Membership in it by a foreigner is a signal honor.

Professor CAMPBELL has also been requested to serve on an honorary committee presided over by the Minister of Public Instruction for France, whose purpose is to forward the project for erecting a monument to the eminent astronomer JEROME LALANDE, at Bourg, the place of his birth.

R. G. A.

GENERAL NOTES.

At the meeting of the American Association for the Advancement of Science held in St. Louis, four papers upon astronomical subjects were presented before Section A, Mathematics and Astronomy. The papers were:—

The Rotation Period of the Planet *Saturn:* G. W. Hough, Director of Dearborn Observatory, Evanston, Ill.

Facilities for Astronomical Photography in Southern California: E. L. Larkin, Director of Lowe Observatory.

The Supporting and Counterweighting of the Principal Axes of Large Telescopes: C. D. Perrine, Lick Observatory.

A New Type of Transit-Room Shutter: David Todd, Director of Amherst College Observatory.

The fifth meeting of the Astronomical and Astrophysical Society of America was held in St. Louis during Convocation week, in affiliation with the American Association for the Advancement of Science. Professor Simon Newcomb was re-elected President of the Society. The list of papers presented, abstracts of which may be found in *Science* for February 19th, was as follows:—

The Prediction of Occultations of Stars by the Moon: G. W. Hough.

The D. O. Mills Expedition: W. W. Campbell.

The Sun's Motion Relative to a Group of Faint Stars: G. C. Comstock.

The Absorption of the Solar Radiation by the Sun's Atmosphere: F. W. Very.

Borrelly's Comet: Sebastian Albrecht.

The Pivots of the Nine-Inch Transit-Circle of the U. S. Naval Observatory: W. S. Eichelberger.

A Short Sketch of the Progress of Astronomy in the United States: M. S. Brennen.

The *Eros* Parallax Photographs at the Goodsell Observatory: H. C. Wilson.

The following notes have been taken from recent numbers of *Science*.

The grant of the Carnegie Institution to the Department of Astronomy of Princeton University has been increased to $1.200. This money is to be used in determining the brightness of certain standard stars.

The death is announced of M. CALLANDREAU, member of the Paris Academy of Sciences in the section of Astronomy.

Professor HERMANN STRUVE, Director of the Observatory at Königsburg, has been appointed Director of the Observatory at Berlin.

Sir WILLIAM HUGGINS, President of the Royal Society, celebrated his eightieth birthday on February 7th.

An observatory has been established at Lagreb, the capital of Croatia (Hungary), and is under the direction of Professor OTTO KUCERA. It has equatorials of 6.4 and 4.25 inches aperture, and it is proposed to observe the Sun, planets, and variable stars.

The next meeting of the Astronomical and Astrophysical Society of America will be held, in affiliation with the American Association for the Advancement of Science, at Philadelphia, during Convocation week, 1904-1905.

The *Astronomical Journal* No. 555 contains an important article entitled "Definitive Orbit of Comet 1845 III," by HENRY A. PECK. This was a naked-eye comet and at the time of visibility it was thought that it might be a return of the famous comet observed by TYCHO BRAHE in 1596. Its orbit was computed by D'ARREST, who found that the observations could be equally well satisfied by a parabola, an hyperbola, and an ellipse of 249 years period.

Mr. PECK concludes, however, "that the complete examination of the observations substantiates the parabolic orbit of D'ARREST, while it shows that his ellipse must be abandoned as being contrary to fact."

The Carnegie Institution has granted the sum of $500 to Professor E. P. LEWIS, of the University of California, for the purpose of carrying on spectroscopic work. Professor LEWIS has already published some interesting results of investigations of the spectra of gases under different physical conditions and upon the spectra of mixed gases. The grant from the Carnegie Institution will enable him to purchase improved apparatus and to carry on the experiments upon an enlarged scale.

Dr. LUDENDORFF, of Potsdam, has published (*A. N.* 3918-3920) some interesting results of investigations of the brightness of *e Aurigæ*. The fluctuations in brightness of this star were first discovered in 1821, but the period was not apparent, and it has been classed as an irregular variable. In the fall of 1902 it was found at Potsdam that this star is a spectroscopic binary of probably very long period. Dr. LUDENDORFF finds, from investigation of all the available observations, that this is an *Algol* variable system, composed of two bright stars revolving in a period of 54¼ years, and eclipsing each other every 27⅛ years. The star remains at maximum brightness for over twenty-five years, declines to minimum in 207 days, remains at minimum 313 days, and then returns to maximum in 207 days, to remain again at that brightness for twenty-five years.

Miss CLERKE points out, however, (*The Observatory*, March, 1904,) from the data given, that the mass of the system must be 188,000 times that of the Sun. She thinks, therefore, that Dr. LUDENDORFF's theory, as it stands, is untenable.

His Excellency the United States Ambassador attended the annual meeting of the Royal Astronomical Society yesterday to receive the gold medal which the council have awarded to Professor GEORGE E. HALE, of the Yerkes Observatory. In his presidential address Professor H. H. TURNER recounted the splendid achievements of Professor HALE, chief of which has been his invention of the spectroheliograph, "by which photographs are now made of all the prominences visible round the entire circumference of the Sun, with a single exposure, and by which faculæ are clearly shown even in the brightest portion of the Sun's disc." The Sun being the only star we can observe in detail, Professor HALE's method enables the astronomer to get over the difficulty of the excessive brightness of the solar orb and photograph the whole surface. In making the presentation, Dr. TURNER referred to the eminent services which American men of science have rendered to astronomy.

Acknowledging the gift of the medal on behalf of Professor HALE, who was unable to be present, Mr. CHOATE observed that this award was the greatest honor which an astronomer could receive. He was gratified to see how highly the work of American observers was esteemed, and to remember that only three years ago this medal was bestowed on Professor PICKERING, of Harvard. Our astronomers, he added, have rare facilities. Heaven smiles upon them. With three hundred clear days and nights in the year—which I am afraid you cannot have here in London—[laughter]—with splendid observatories provided and equipped with public and private munificence, it would be strange if they did not do well. This gift will add further stimulus to Professor HALE, and to give stimulus and nerve to such a man is to achieve the highest purpose of such an award. [Loud cheers.]—*London Daily Telegraph, Feb. 15th.*

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, ON SATURDAY, NOVEMBER 28, 1903, AT 2 P.M.

President VON GELDERN presided. A quorum was present.

The purpose of the meeting being the Fifth Award of the Bruce Gold Medal, the letters received from the Directors of the six nominating Observatories were submitted by the Secretary. After a careful consideration of the recommendations contained in these letters, the selection of the Medalist was made by ballot, and the following certificate of bestowal was signed by all Directors present:—

SAN FRANCISCO, November 28, 1903.

FIFTH AWARD OF THE BRUCE MEDAL.

We, the undersigned Directors of the Astronomical Society of the Pacific, hereby certify, that, in accordance with the Statutes for the bestowal of the Bruce Medal, a special meeting of the Board of Directors was held this day, at two o'clock P.M., for the purpose of awarding the medal for the year 1904; and that, the provisions of the Statutes relating to its bestowal having been complied with, the medal was awarded to—

WILLIAM HUGGINS,

for Distinguished Services to Astronomy, by the consenting votes of eleven Directors.

Signed: R. G. AITKEN,* CHAS. BURCKHALTER, W. W. CAMPBELL,* WM. H. CROCKER,* CHAS. S. CUSHING,* OTTO VON GELDERN, A. O. LEUSCHNER, E. J. MOLERA,* WM. M. PIERSON,* S. D. TOWNLEY,* F. R. ZIEL.

Adjourned.

(* By proxy.)

In answer to a letter addressed to Sir WILLIAM HUGGINS, notifying him of the action taken by the Directors, the following letter of acceptance was received:—

LONDON, 15 January, 1904.

DEAR SIR: I beg to acknowledge the receipt of your letter of the 1st inst., informing me of the high honour which the Board of Directors of the Astronomical Society of the Pacific have conferred upon me by the award to me of the "Bruce Gold Medal" for the year 1904. In accordance with the Statute to which you call my attention, I beg herewith to express formally my grateful acceptance of this mark of high distinction bestowed upon me by your Society; I shall always look upon the medal as among the most prized of my possessions.

I have the honour to remain,

Yours very faithfully,

WILLIAM HUGGINS.

To F. R. ZIEL, Esq.,

Secretary Astronomical Society of the Pacific.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, MARCH 26, 1904, AT 7:30 P.M.

President VON GELDERN presided. A quorum was present. The minutes of the last meeting were read and approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED MARCH 26, 1904.

OAKLAND FREE PUBLIC LIBRARY....	Oakland, Cal.
Mr. E. J. DE SABLA, JR.*.........	615, Rialto Building, S. F., Cal.
Dr. A. S. TUCHLER................	N. W. cor. Van Ness Ave. and Turk St., S. F., Cal.

REPORT OF THE LIBRARY COMMITTEE.

The Library Committee presented its report, as follows, and the report was accepted and filed:—

SAN FRANCISCO, CAL., March 26, 1904.

To the Board of Directors of the Astronomical Society of the Pacific:

We, the undersigned Committee of the Society's Library, report as follows:

Since the last annual report the manuscript catalogue, authorized by the Board of Directors, has been completed and will be published in the August number of the *Publications*.

By binding, purchase, and gift the number of volumes on the accessions-book has been increased during the past year from 1,258 to 1,344.

The expenditures from the Alexander Montgomery Library Fund may be found in the Treasurer's report.

Respectfully submitted,
SIDNEY D. TOWNLEY, *Librarian.*
ROSE O'HALLORAN.

The Finance Committee reported that, pursuant to the Resolution adopted March 28, 1903, authorizing the investment of the funds of the Society in bonds, they had bought eight bonds, at a total cost of $8,059.44;—an itemized account of the cost and distribution of these bonds among the several funds being contained in the Treasurer's Report.

Adjourned.

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* A star denotes Life Membership.

MINUTES OF THE SIXTEENTH ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, MARCH 26, 1904, AT 8 P.M.

The meeting was called to order by President VON GELDERN. A quorum was present. The minutes of the last meeting were approved. The Secretary read the names of new members duly elected at the Directors' meeting.

The following papers were presented:—

1. Address of the retiring President of the Society, by OTTO VON GELDERN.
2. Reports of Committees: on Nominations; on the Comet Medal; on the Library on Auditing; and Annual Report of the Treasurer.
3. Photographs of Comet Borrelly, by SEB. ALBRECHT.
4. Variable Star Notes, by Miss O'HALLORAN.
5. A Few Details of the Twelve-Year Sun Spot Cycle, by Miss O'HALLORAN.
6. Planetary Phenomena for May and June, 1904, by M. MCNEILL.
7. The Supporting and Counterweighting of the Principal Axes of Large Telescopes, by C. D. PERRINE.

The Committee on Nominations reported a list of names proposed for election as Directors, as follows: Messrs. R. G. AITKEN, CHAS. BURCKHALTER, W. W. CAMPBELL, WM. H. CROCKER, CHAS. S. CUSHING, GEO. C. EDWARDS, A. O. LEUSCHNER, GEO. C. PARDEE, WM. M. PIERSON, S. D. TOWNLEY, F. R. ZIEL.

For Committee on Publication: Messrs. R. G. AITKEN (Chairman), FRANK SCHLESINGER, S. D. TOWNLEY.

Messrs. SCHIRMAN and ATKINS were appointed as tellers. The polls were open from 8:15 to 9 P.M., and the persons above named were duly elected to serve for the ensuing year.

REPORT OF THE COMMITTEE ON THE DONOHOE COMET-MEDAL.

Submitted March 26, 1904.

This reports relates to the Calendar year 1903. The Comets of 1903 have been:—

Comet *a* (unexpected comet), discovered by M. GIACOBINI, at Nice, on January 15th.

Comet *b* (unexpected comet), discovered by Mr. JOHN GRIGG, at Thames, N. Z., on April 16th.

Comet *c* (unexpected comet), discovered by M. BORRELLY, at Marseilles, France, on June 21st.

Comet *d* (BROOKS's periodic comet, 1889 V, 1896 VI), observed on its return by R. G. AITKEN, at the Lick Observatory, August 18th.

In accordance with the Statutes, Donohoe Comet-Medals have been awarded to the discoverers of Comets *a*, *b*, and *c*.

W. W. CAMPBELL,
CHAS. BURCKHALTER,
WM. M. PIERSON,
Committee on the Donohoe Comet-Medal.

The Treasurer submitted his Annual Report as follows:—

ANNUAL STATEMENT OF THE RECEIPTS AND EXPENDITURES OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE FISCAL YEAR ENDING MARCH 26, 1904.

GENERAL FUND.

Receipts.

1903, March 29th. Cash Balance			$5,414 68
Received from dues for 1903 and previous years	$280 97		
" " " " 1904	571 40		
" " Life membership fee	50 00	$902 37	
" " sale of Publications		54 00	
" " Life Membership Fund (interest)		56 67	
" " John Dolbeer Fund (interest)		107 74	1,120 78
			$6,535 46
Less transfer to John Dolbeer Fund		$5,000 00	
" " " Life Membership Fund		50 00	5,050 00
			$1,485 46

Expenditures.

For Publications: printing Nos. 89 to 93 of Vol. XV.	$530 70		
" No. 94 of Vol. XVI.	134 50		
illustrations	23 25	$688 45	
Stationery and printing		87 95	
Postages		65 32	
Rent		180 00	
Salary Secretary-Treasurer		180 00	
Expressages		11 15	
Telephone and Telegrams		2 25	
Janitor		4 00	
Gas		1 55	
Insurance premiums		24 00	
Lantern at lecture		8 50	
Engrossing diplomas		9 00	
Taxes		2 70	
Bank Exchanges		10	
Rent safe deposit box		5 00	1,269 97
1904, March 26th. Cash Balance			$ 215 49

LIFE MEMBERSHIP FUND.

1903, March 29th. Cash Balance	$1,703 95
Received from General Fund	50 00
Interest for 1903	56 67
	$1,810 62
Less transfer to General Fund (interest)	56 67
1904, March 26th. Cash Balance	$1,753 95

ALEXANDER MONTGOMERY LIBRARY FUND.

1903, March 29th. Cash Balance		$1,515 14
Interest for 1903		48 33
		$1,563 47
Less expenditures:		
Astrophysical Journal, 2 Nos.	$ 1 00	
Astronomischer Jahresbericht, Vols. II and III	9 81	
Hicks-Judd Co., binding	66 13	
Himmel & Erde, Vol. III	75	
Popular Astronomy, subscription, Nos. 111 to 120	2 50	
Astronomical Journal, Vols. 20, 21, 22	9 75	
Astronomische Nachrichten, Vols. 159, 160, 161	7 92	
Checking card catalogue and card index	10 00	
Preparing Manuscript Catalogue of bound books	40 00	147 86
1904, March 26th. Cash Balance		$1,415 61

DONOHOE COMET-MEDAL FUND.

1903, March 29th. Cash Balance	$705 58
Interest for 1903	23 30
	$728 88
Less engraving medals Nos. 43, 44, 45, and postage	4 53
1904, March 26th. Cash Balance	$724 35

BRUCE MEDAL FUND.

1903, March 29th. Cash Balance	$2,548 79
Interest for 1903	79 64
	$2,628 43
Less remittance to A. DUBOIS, Paris, (fifth award)	101 95
1904, March 26th. Cash Balance	$2,526 48

JOHN DOLBEER FUND.

1903, March 30th. Payment by General Fund	$5,000 00
Interest for 1903	107 74
	$5,107 74
Less transfer to General Fund (interest)	107 74
1904, March 26th. Cash Balance	$5,000 00

FUNDS.

Balances as follows:

General Fund:		
with Donohoe-Kelly Banking Co		$215 49
Life Membership Fund:		
with San Francisco Savings Union	$ 303 95	
" German Savings and Loan Society	250 00	
" Hibernia Savings and Loan Society	200 00	
South Pacific Coast Railway Co., 1st Mortgage 4% guaranteed (by S. P. Co.) $1,000 Gold Bond, No. 3,406 (Principal due July 1, 1937; interest Jan. 1 and July 1.)	1,000 00	1,753 95
Alexander Montgomery Library Fund:		
with San Francisco Savings Union	$ 165 89	
" German Savings and Loan Society	138 06	
" Hibernia Savings and Loan Society	71 66	
Oakland Transit Consolidated, 1st consolidated Mortgage 5% $1,000 Gold Bond, No. 4,328 (Principal due July 1, 1932; interest Jan. 1 and July 1.)	1,040 00	1,415 61
Donohoe Comet-Medal Fund:		
with San Francisco Savings Union	$ 224 64	
" German Savings and Loan Society	245 26	
" Hibernia Savings and Loan Society	254 45	724 35
Bruce Medal Fund:		
with San Francisco Savings Union	$ 215 49	
" Security Savings Bank	159 11	
" German Savings and Loan Society	162 16	
Bay Counties Power Co., 1st consolidated Mortgage 5% $1,000 Sinking Fund Gold Bond, No. 1,636 (Principal due Sept. 1, 1930; interest Mar. 1 and Sept. 1.)	1,012 50	
The Edison Electric Co., Los Angeles, 1st and Refunding Mortgage 5% $1,000 Gold Bond, No. 168 (Principal due Sept. 1, 1922; interest Mar. 1 and Sept. 1.)	977 22	2,526 48
John Dolbeer Fund:		
with Union Trust Co.	570 28	
" Mutual Savings Bank	400 00	
South Pacific Coast Railway Co., 1st Mortgage 4% guaranteed (by S. P. Co.) $1,000 Gold Bond, No. 3,407 (Principal due July 1, 1937; interest Jan. 1 and July 1.)	1,000 00	
Oakland Transit Consolidated, 1st consolidated Mortgage 5% $1,000 Gold Bond, No. 4,329 (Principal due July 1, 1932; interest Jan. 1 and July 1.)	1,040 00	
Bay Counties Power Co., 1st consolidated Mortgage 5% $1,000 Sinking Fund Gold Bond, No. 1,637 (Principal due Sept. 1, 1930; interest Mar. 1 and Sept. 1.)	1,012 50	
The Edison Electric Co., Los Angeles, 1st and Refunding Mortgage 5% $1,000 Gold Bond, No. 169 (Principal due Sept. 1, 1922; interest Mar. 1 and Sept. 1.)	977 22	5,000 00
		$11,635 88

San Francisco, March 26, 1904.

F. R. ZIEL, *Treasurer.*

Examined and found correct.

Chas. S. Cushing,
Daniel Suter, } *Auditing Committee.*

The report was, on motion, accepted and filed.

The Committee appointed to audit the Treasurer's accounts reported as follows, and the report was, on motion, accepted and adopted:—

San Francisco, Cal., March 26, 1904.

To the President and Members of the Astronomical Society of the Pacific:

Gentlemen — Your committee appointed to audit the accounts of the Treasurer for the fiscal year ending March 26, 1904, has made a careful examination, and found the same to be correct. Respectfully submitted,

Chas. S. Cushing, } *Auditing Committee.*
Daniel Suter, }

The President then read his annual address awarding the Bruce Medal for the year 1904, to Sir William Huggins for distinguished services to Astronomy.

Dr. Townley gave an account of the work being done at the Latitude Observatory at Ukiah.

The following resolution was, on motion, adopted:—

Resolved, That all the acts appearing in the minutes of the meetings of the Board of Directors of this Society, as having been done by said Board during the past fiscal year, are here now, by this Society, approved and confirmed.

Adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, MARCH 26, 1904, AT 9:30 P.M.

The new Board of Directors was called to order by Mr. LEUSCHNER. A quorum was present. The minutes of the last meeting were approved.

The first business in hand being the election of officers for the ensuing year, the following officers, having received a majority of the votes cast, were duly elected:—

President: Mr. GEO. C. EDWARDS.
First Vice-President: Mr. S. D. TOWNLEY.
Second Vice-President: Mr. CHAS. S. CUSHING.
Third Vice-President: Mr. A. O. LEUSCHNER.
Secretaries: Messrs. R. G. AITKEN and F. R. ZIEL.
Treasurer: Mr. F. R. ZIEL.

The President was authorized to appoint the standing committees of the Society, and made the following selections:—

Committee on the Comet-Medal: Messrs. CAMPBELL (*ex-officio*), PIERSON, BURCKHALTER.

Library Committee: Messrs. TOWNLEY, BABCOCK, Miss O'HALLORAN.

Mr. TOWNLEY was appointed Librarian.

Finance Committee: Messrs. CUSHING (*Chairman*), PIERSON, LEUSCHNER.

The Committee on Publication is composed of: Messrs. R. G. AITKEN (*Chairman*), FRANK SCHLESINGER, S. D. TOWNLEY.

The Board of Directors is composed of: Messrs. AITKEN, BURCKHALTER, CAMPBELL, CROCKER, CUSHING, EDWARDS, LEUSCHNER, PARDEE, PIERSON, TOWNLEY, and ZIEL.

The following resolutions were, upon motion, duly adopted:—

***Resolved*, That the income from the John Dolbeer Fund be in future devoted to specific purposes, and that it shall become available only through a resolution duly adopted at a regular or special meeting of the Board of Directors; provided, however, that the income for the fiscal year 1904-1905 be devoted to the *Publications* of the Society, and that an acknowledgment to the Dolbeer Fund be printed in the *Publications*.**

***Resolved*, That the amount to be withdrawn from the General Fund or publication purposes during the fiscal year 1904-1905 shall not exceed the sum of $500.**

***Resolved*, That the names of the members of the Committee on Publication be printed on the inside of the front page of the cover of the *Publications*.**

***Resolved*, That the new catalogue of the bound books be published as the August number of Vol. XVI of the *Publications*.**

***Resolved*, That the name of the Société Belge d'Astronomie, of Brussels, Belgium, be placed on the list of corresponding institutions.**

***Resolved*, That the opening of the safe deposit box of the Society with the California Safe Deposit and Trust Co. be intrusted to the following committee of two members of the Board of Directors, jointly, namely, F. R. ZIEL (Secretary), and CHAS. S. CUSHING (Chairman of the Finance Committee), and that the California Safe Deposit and Trust Co. shall be officially notified of any change in the names of the Committee, in writing, by the President and Secretary, under the seal of the Society.**

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. Geo. C. Edwards	*President*
Mr. S. D. Townley	*First Vice-President*
Mr. Chas. S. Cushing	*Second Vice-President*
Mr. A. O. Leuschner	*Third Vice-President*
Mr. R. G. Aitken Mr. F. R. Ziel	*Secretaries*
Mr. F. R. Ziel	*Treasurer*

Board of Directors—Messrs Aitken, Burckhalter, Campbell, Crocker, Cushing, Edwards, Leuschner, Pardee, Pierson, Townley, Ziel.

Finance Committee—Messrs. Cushing, Pierson, Leuschner.

Committee on Publication—Messrs Aitken, Schlesinger, Townley.

Library Committee—Messrs. Townley, Babcock, Miss O'Halloran.

Committee on the Comet-Medal—Messrs. Campbell (*ex-officio*), Pierson, Burckhalter.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Felipe Valle.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

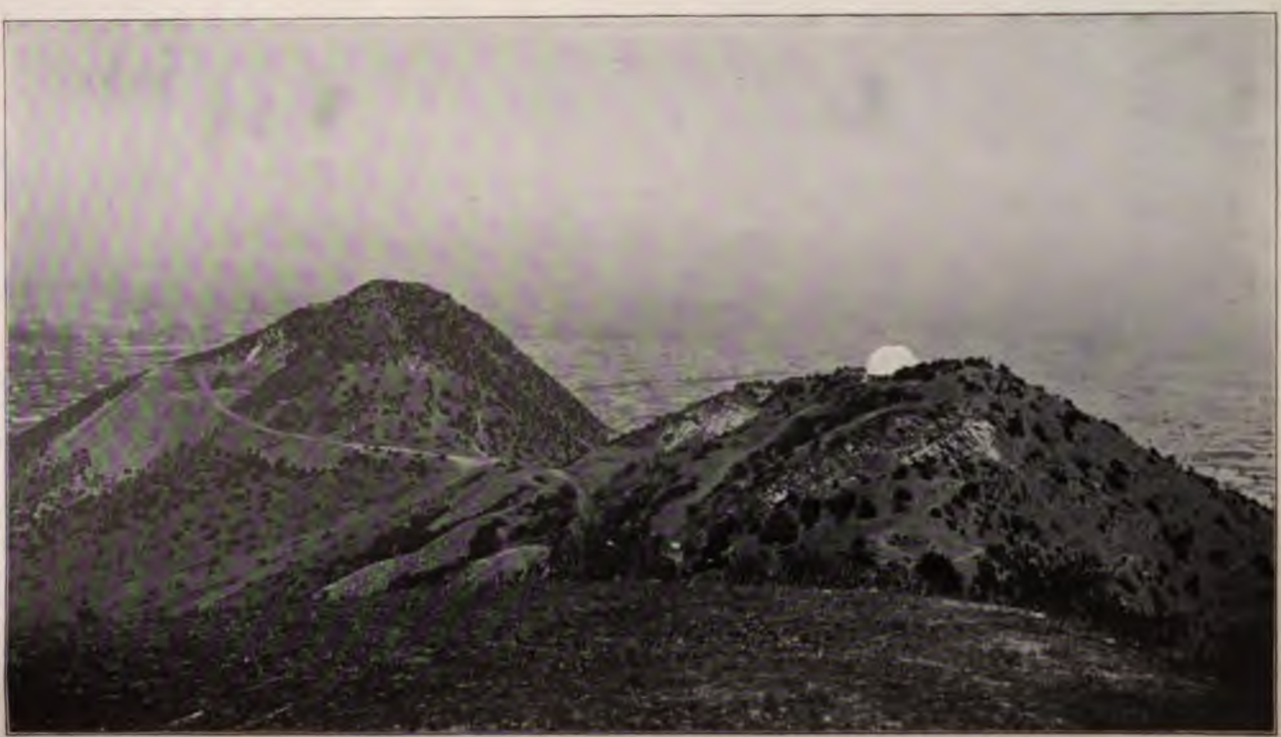
The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

THE
PUBLIC

ASTOR, LENOX AND
TILDEN FOUNDATIONS



THE OBSERVATORY ON SAN CRISTOBAL.

(SANTIAGO IN THE BACKGROUND.)

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XVI. SAN FRANCISCO, CALIFORNIA, JUNE 10, 1904. No. 96.

A BRIEF REVIEW OF RECENT PROGRESS IN SOLAR PHYSICS.

By HEBER D. CURTIS.

ANNALES L'OBSERVATOIRE D'ASTRONOMIE PHYSIQUE DE PARIS, SIS PARC À MEUDON. Tome I, 1896.

—ATLAS DES PHOTOGRAPHIES SOLAIRES. Tome I, 1903.

THE RUMFORD SPECTROHELIOGRAPH OF THE YERKES OBSERVATORY. *Publications of the Yerkes Observatory,* Vol. III, Part I, 1903.

ANNALS OF THE ASTROPHYSICAL OBSERVATORY OF THE SMITHSONIAN INSTITUTION. Vol. I, 1900.

INTENSITÉ DE LA RADIATION SOLAIRE A DIFFÉRENTES ALTITUDES. RECHERCHES FAITES A TÉNÉRIFFE 1895 ET 1896 PAR KNUT ÅNGSTRÖM. Nova Acta Reg. Sec. Scient. Upsaliensis XX, fasc. I, 1901.

REPORT OF THE COMMITTEE ON SOUTHERN AND SOLAR OBSERVATORIES. Published by the Carnegie Institution, 1903.

Although the researches covered by these superbly printed volumes in some cases reach back twenty years or more, the recent publication of the results secured may warrant a brief résumé of the progress recorded in these epoch-marking monographs.

It is a far cry from the first daguerreotype of the Sun, made in 1845 by FIZEAU and FOUCAULT, to the great plates of the Meudon folio, photographed for the most part on a scale of $0^{m}.30$ to the Sun's diameter and enlarged to a solar diameter of $1^{m}.20$. In the volume of the Annals the plates have been enlarged to a solar diameter of $0^{m}.894$; and as the plates given in the Atlas cover the same general ground and the letter-press is practically a reprint of that in the Annals, it is possible that many will consider the partial duplication of work in the Atlas an expenditure not warranted by the additional results made accessible. There can be no question, however, as to the beauty of this fine folio, or the excellence of its great prints, nearly eighteen by twenty-one inches in size. The photographs were secured with a telescope and lens by PRAZMOWSKI, $0^{m}.135$ (5.3 in.) in aperture, described by M. JANSSEN as of rare optical perfection. In the taking of the plates of this series as large as possible a measure of monochromatism was sought for. This result has been achieved by careful choice and figuring of the glass of the lens to secure a sharply defined maximum of photographic effect near G. In like manner the collodion plates employed were composed from formulæ found by experiment to give a similar maximum, quite limited in extent, at the same region of the spectrum, and great pains were taken and special precautions employed in the manufacture of the collodion emulsion to secure plates of exceeding fineness of grain. The negatives were generally on a scale of $0^{m}.30$, though sometimes $0^{m}.50$, or even $0^{m}.70$, was employed. Some of the plates show a sharpness and fineness of detail which it would be difficult to improve. Plates I, III, XIX, and XXI are unusually good. The average size of the granulations is from one to two seconds of arc, though not infrequently details can be seen measuring not more than one fourth to one third of a second.

One of the more important of M. JANSSEN's results, aside from the granular structure itself and the relegation of "willow-leaf" to the limbo of discarded theory, is the fact that the granular structure generally persists right up to the visually much brighter edge of spots and through the striæ of spot penumbræ. Moreover, there seems to be no essential difference in the granulations at the poles as compared with the central regions. Many of the plates show quite plainly the so-called *réseau photosphérique*, or network, in which these granulations are frequently arranged, generally of a roughly polygonal form. The nature of the granulations seems to be entirely analogous to roughly spherical clouds floating in a

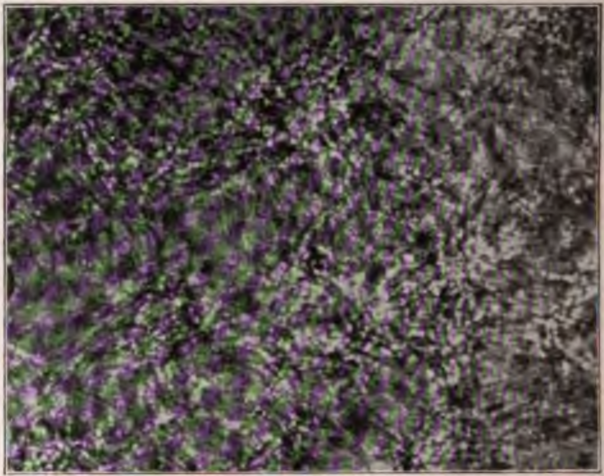


FIGURE 1.—A portion of Plate IX, *Meudon Atlas des Photographies Solaires.*

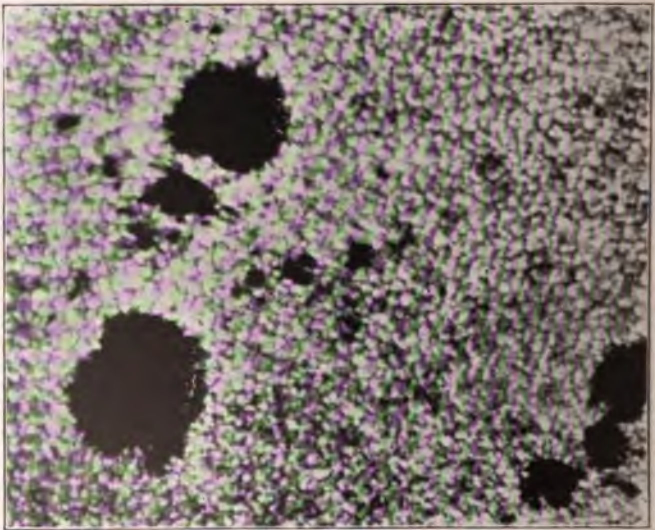


FIGURE 2.—A portion of Plate XIX, *Meudon Atlas des Photographies Solaires.*

less luminous medium. JANSSEN estimates that were the entire solar surface of the same radiating power as the granulations the intensity of the solar radiation would be quintupled. The *réseau* JANSSEN holds to be a result of different stages in the development of the granulations. The solar surface is composed of sections relatively quiescent while adjacent regions are in a condition of great activity. This can be seen easily in Figure 1, which is a small section of Plate IX of the Atlas, on nearly the same scale. Where the regions of quiescence obtain the granulations are sharp and well-defined. In adjacent regions of greater activity the separate grains merge into a more or less confused whole, the sum total giving the effect of a network or pattern. Sometimes the figures of the "pattern" are much smaller than at others, and at times they may be a minute of arc or more in diameter. In Figure 2, taken from Plate XXI, the network is wanting, and the granulations are very well defined and show an approximately spherical form.

M. JANSSEN's theory of the *réseau photosphérique* has been given here, although it has more than once been called in question. It has been pointed out that this phenomenon may instead be produced in our own atmosphere, or even within the telescope itself. It has often been asked why two photographs could not be taken very close together to settle this objection once for all (*cf.*, among others, LANGLEY, *Amer. Jour.*, XV., pp. 297 ff.). This may be more difficult than it seems, as the conditions of good seeing necessary for a perfect plate are generally very brief. But it would seem to be possible to take two such plates, and that even if one was of inferior quality, definite evidence as to the true solar character of the *réseau* might be secured. No more recent statement of this hypothesis is given in these volumes than M. JANSSEN's original announcement of discovery made in 1877 and reprinted in both the Annals and the Atlas. In view of Dr. HALE's experiences with brief intervals of poor seeing in his spectroheliographic work and Professor LANGLEY's experiments on improved images secured by mechanical stirring of the air in the telescope-tube or immediately in front of the lens, the solar character of the *réseau* would seem to be open to doubt till absolutely confirmed by consecutive exposures at brief intervals.

The Meudon photographs are to
monochromatic, as they are taken wit
and sharply limited portion of the spec
perhaps the highest present developme
solar surface from methods purely photo
In the researches of Dr. HALE an
ELLERMAN, we have this principle of m
to its logical conclusion, and with the a
graph it is now possible to take photog
face in light which is purely monochr
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but must require a very high degree of
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gives the entire area in light which is
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The volume gives a description of th
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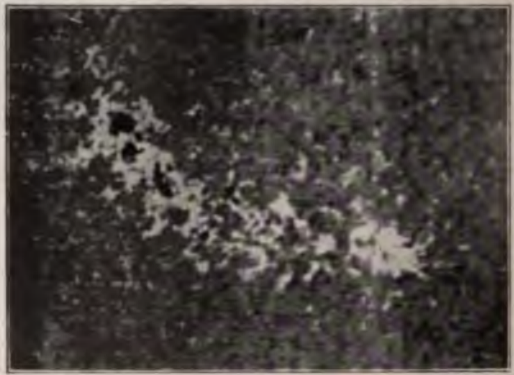

FIGURE 3.—Calcium Flocculi, photographed with light from the lower K_1 level.

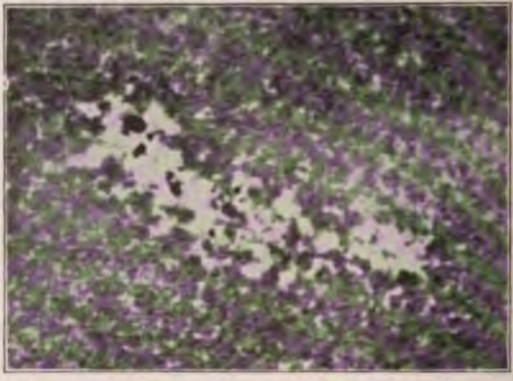

FIGURE 4.—The same Flocculi photographed with light from the K_2 level.

(Figures 3 and 4 are from *Publ. Yerkes Obs.*, Vol. III., Part I., Plate V.)

instruments, and a statement of the results thus far secured. By this method Dr. HALE has taken numerous photographs by the light from different portions of the H and K bands, the calcium line at λ 4226 and H_β. Attempts have also been made to use some of the stronger iron lines, but for this latter purpose it is found that a more powerful equipment will be needed.

In general the calcium "flocculi" photographed with light from H and K are of dimensions about the same as those of the granulations on the Meudon photographs, and are probably different views of the same formation. But the greatest interest attaches to the photographs made in light of different wave-lengths of the same substance. Marked differences are found, according as the calcium flocculi are photographed in light of the H and K bands at their broadest, called by the authors H_1 and K_1, or in their narrowed state as they appear in the lower levels of the chromosphere (H_2. K_2). Eventually it is hoped to be able to secure impressions with these lines in their still narrower state as they appear in the upper chromosphere and prominences (H_3, K_3). It will be noted in Figures 3 and 4 that the photograph from light at the K_2 level shows the flocculi spread over a much greater area than the plates taken at the lower levels of K_1. Undoubtedly these differences are due to the fact that these photographs represent different *levels* of the calcium vapor in the flocculi. We get, then, in effect, several *cross-sections* of a flocculus, and in general the evidence points to a "structure composed of expanding columns of calcium vapor." Considerable differences have likewise been found between photographs made with H and K light, as compared with those taken from the calcium line at λ 4226.9 — differences which the authors prefer to leave for tests with more powerful apparatus to explain. *Dark* calcium flocculi have also been photographed. The photographs taken with light from the hydrogen line at H_β show that the flocculi due to this element are in general dark, though bright in exceptional cases. The hope is expressed that with a larger solar image and higher dispersion it may later be possible to photograph the hydrogen flocculi at different levels as has already been done for calcium.

It would be futile to try to estimate the importance of this advance in methods for the study of all solar eruptive phenomena. It is not improbable that much evidence will eventually be secured on theories of dissociation and chemical combination in fields but remotely connected with astronomical science. The essentials for future progress in photoheliographic work are a larger solar image, greater dispersion in the instrument, and, most important, good day conditions of "seeing," requirements which are now being secured.

No outline of recent progress in solar physics would be complete without reference to the bolometric work of the Astrophysical Observatory of the Smithsonian Institution. As in the case of some of the other volumes noted in this summary, inasmuch as the work covered dates back over twenty years to its inception by Professor LANGLEY, it might be more fitting to regard it as a recently erected landmark of past progress. Under Professor LANGLEY at Allegheny and the Smithsonian Institution, and later in the skilled hands of ABBOT, the original bolometer has been improved with the use of prisms of rock-salt, constant-temperature control, almost automatic photographic registration of results, and galvanometers of the most extreme sensitiveness, till the infra-red spectrum has been mapped from λ 7600, the limit of the visual spectrum, to λ 53000, a stretch of previously unknown spectrographic territory eight times as large as all that had been known before. Aside from its purely theoretical interest, the study of this long stretch of invisible solar thermal radiation, the determination of the circumstances of its absorption by our atmosphere, and its possible variations during a sun-spot period are questions of the highest economic importance.

In this connection the observations of the solar constant made simultaneously at different altitudes on the island of Ténériffe by ANGSTRÖM are of interest. His work is noted here not because of any novelty in the results, for other similar investigations have been carried out, but because in the employment of the compensation pyrheliometer devised by him we have what will probably prove to be a very distinct advance over former instrumental means for determining the solar constant. Though described in the Upsala publications and also in the *Astrophysical Journal* (Vol. IX, pp. 399 ff.), a brief outline of its principle may not be out of place. Two precisely similar blackened strips of platinum are connected with the terminals of a thermopile. One of these strips is exposed to the rays of the Sun, the other is covered by a screen. The rise in temperature in the exposed strip is compensated in the screened strip, and at the same time measured, by electrically heating it the same amount, the thermopile, in connection with the employment of delicate electrical measuring devices, forming a very sensitive thermal balance. As the strip which receives the radiation is under precisely the same conditions as the strip which measures the amount of the radiation, many troublesome corrections are obviated and the speed of the determinations is very much higher than in other forms, a few seconds instead of three to five minutes or longer.

Plans for the future are frequently the best norm of past progress. The Report of the Committee of the Carnegie Institution on Southern and Solar Observations is a most clear, definite, and straightforward presentation of the most pressing present-day problems in astronomy and astrophysics. The report makes very interesting reading, and it gives indirectly, through its plans for future work, a clear conspectus of the present boundaries in these sciences. Astronomers cannot fail to feel that the committee has wisely and without bias chosen the most fruitful lines for future research in astronomy and astrophysics; this the more, as the report is in many ways a summation of the opinions of the leaders, both American and foreign, in these sciences. An appendix is devoted to these opinions in the form of letters written to the committee, and they show on the whole great unanimity.

The recommendations for the solar observatory contemplate a main station and two substations. At the main station, aside from researches on stars and nebulæ, the solar work will be limited to two or three definite lines of research.

(1) "Frequent measurement of the solar constant, together with studies on the absorption of the solar atmosphere and the radiation of different portions of the Sun's image, such as spots, faculæ, and prominences. The principal instruments needed for this research are a 16-inch cœlostat and a large spectrobolometer for the solar constant work, and a 30-inch cœlostat with concave mirror of about 200 feet focal length,

for providing a solar image suitable for detailed radiation work."

(2) "Systematic observations, with large spectrographs and spectroheliographs, on such problems as the solar rotation, the structure and nature of sun-spots, faculæ, etc., and other problems related to the solar constitution. For this work there will be required two 30-inch cœlostats, used in conjunction with objectives and mirrors ranging in focal length from 64 feet to 200 feet; two large plane-grating spectroscopes, having focal lengths of about 21 feet and 42 feet respectively, provided with auxiliary for work with the spark and arc; a three prism spectroheliograph of about 10 inches aperture, and a three-prism spectroheliograph of 8 inches aperture and about 33 feet focal length."

Great care has been taken that no mistake should be made in the selection of the site for this important station, and in an appendix is given the full and interesting report of Professor W. J. HUSSEY's thorough search for the best conditions of seeing obtainable at several elevated sites in Southern California and Arizona. In the use of a large solar image, which is so essential to further progress in spectroheliographic work, good day conditions are absolutely required. Professor HUSSEY's investigations show that Mt. Wilson, near Pasadena, is possessed of unusually favorable conditions of seeing, both by day and by night. Professor HUSSEY's further report on his search for suitable sites in Australia will be awaited with great interest.

It is gratifying to be able to add, from press reports, that Dr. HALE has been given a preliminary grant of $10,000 by the Carnegie Institution, and that he, with two assistants, is now installing the Snow horizontal telescope of the Yerkes Observatory and other apparatus at the summit of Mt. Wilson.

The two projected substations are to be devoted primarily to the determination of the solar constant at different altitudes, and its possible variation, together with researches on atmospheric absorption. The instruments needed would be the same at each station, a 10-inch cœlostat and spectrobolometer for the solar-constant work. One station will be located on as high a mountain as will be found practicable and the other at its base. Mt. Whitney has been suggested as a very favorable site, but this point will be investigated further before any definite recommendation is made as to the location of the substations. It is purposed to continue the work at the main station throughout at least one sun-spot period, and for two or three summers at the two substations.

With the foresight and thoroughness with which the committee has made its plans and preliminary investigations as an earnest of the wise future administration of its trust, with the powerful equipment for which these recommendations call, and with plans founded on the notable advances of the past twenty years, astrophysicists may well hope for a decade of unparalleled progress in the field of solar physics.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1904.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter,	July	5,	$8^h\,54^m$ P.M.	Last Quarter,	Aug.	4,	$6^h\,3^m$ A.M.
New Moon,	"	12,	9 27 P.M.	New Moon,	"	11,	4 58 A.M.
First Quarter,	"	19,	12 49 P.M.	First Quarter,	"	17,	8 27 P.M.
Full Moon,	"	27,	1 42 A.M.	Full Moon,	"	25,	5 2 P.M.

The Earth is in aphelion July 4th, 5 P.M., Pacific time.

Mercury is a morning star on July 1st, too near the Sun to be seen, rising about three quarters of an hour before sunrise. It rapidly approaches the Sun, passes superior conjunction, and becomes an evening star on July 9th. By August 1st it has receded far enough from the Sun to set rather more than an hour after sunset, and this interval does not change very much until after the middle of the month. It reaches greatest east elongation on the evening of August 19th. Its apparent distance from the Sun will then be $27^\circ\ 24'$. This elongation is much greater than the average greatest elongation, since the planet passed its aphelion on August 17th, only two days before. After passing greatest elongation the planet approaches the Sun quite rapidly, and at the end of the month it sets about half an hour after sunset. It is in close conjunction with *Mars* on the morning of July 2d, but both bodies are almost too near the Sun for observation at that time. Also, it is in conjunction with *Venus* only ten hours after passing conjunction with the Sun.

Venus is a morning star too near the Sun to be easily seen on July 1st. It comes to superior conjunction July 7th, 11 P.M., Pacific time. It then becomes an evening star, and will remain so until the following spring. Its apparent distance from the Sun increases rather slowly, and its path among the stars tends toward the south; so the interval between the setting of the Sun and of the planet does not grow very rapidly. On August 1st it is only thirteen minutes, and on August 31st about forty minutes. Notwithstanding its brightness, now at its minimum, it will not be easy to see it with the naked eye until nearly the close of August. It is in perihelion on July 23d, but its orbit is so nearly circular that the difference between greatest and least distance from the Sun is less than half a million miles.

Mars is now getting far enough away from the Sun to be seen as a morning star. On July 1st it rises about forty minutes before sunrise, on August 1st an hour and a half before, and on August 31st well over two hours before. During the two months it moves over 40° eastward and 6° southward in *Gemini*. During the middle and latter part of August it is a few degrees south of *Castor and Pollux*, α and β *Geminorum*.

Jupiter rises half an hour after midnight on July 1st, and by the end of August at a little before 9 P.M. It moves eastward in the eastern part of *Pisces* until August 20th, about 3°, and then begins to move slowly westward.

Saturn rises before 10 P.M. on July 1st, and at about 5:40 on August 30th. So it is in fair position for early-evening observation in August. It comes to opposition with the Sun on August 10th, and is then above the horizon during the entire night. During the two months it moves about 4° westward in the constellation *Capricorn*, somewhat east of α and β, the principal stars of the constellation. The rings apparently widen out a trifle from their minimum in June, on account of the Earth's motion in reference to their plane; but aside from this temporary increase in apparent breadth, there will be a general progressive diminution until the motion of the planet brings the plane of the rings into coincidence with the Earth.

Uranus crosses the meridian shortly after 11 P.M., on July 1st, and at 7 P.M. on September 1st. So it is in fair position for evening observation. It moves a little less than 2° westward in the western part of *Sagittarius,* becoming stationary early in September. No bright star is near enough to make the planet's identification easy.

Neptune is a morning object in *Gemini.* By the end of August it rises not long after midnight.

It will be worth while to look for the annual *Perseid* meteors during the second week in August. The meteors are so scattered that we get some every year, while there is no great shower occurring at intervals of several years,—or failing to come to time in anything like its hoped for brilliancy, as happened with the *Leonids* a few years ago.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

THE OBSERVATORY OF THE D. O. MILLS EXPEDITION TO CHILE.

The buildings and premises occupied by the D. O. Mills Expedition to Chile are shown in the accompanying illustrations. The station, on the summit of San Cristobal, is about two miles northeast of the center of the city of Santiago, at an elevation of 2,800 feet above sea-level, the altitude of the city being 1,800 feet. The city of Santiago is shown indistinctly in the background of one of the illustrations.

The installation of the apparatus was completed last October, and photographic results accumulated rapidly during the southern summer now coming to a close. The first installment of spectrum plates has just been received at Mount Hamilton, where they will be promptly measured and reduced. A few spectroscopic binaries have been already discovered as by-products of the programme of observations.

W. W. CAMPBELL.

NOTE ON β 346 = *LIBRÆ* 23.

In his General Catalogue BURNHAM gives the measures of this double star from discovery in 1877 to 1888 with the note, "No material change." I have, however, secured two measures recently which seem to indicate that this pair is a binary in slow direct motion. The measures from 1877 to 1888 are rather discordant, varying between 233° and 239°, with a distance of about 1″.25. My recent measures give an angle of 253°.6, with distance 1″.35 (1904.36).

May 27, 1904.

R. G. AITKEN.

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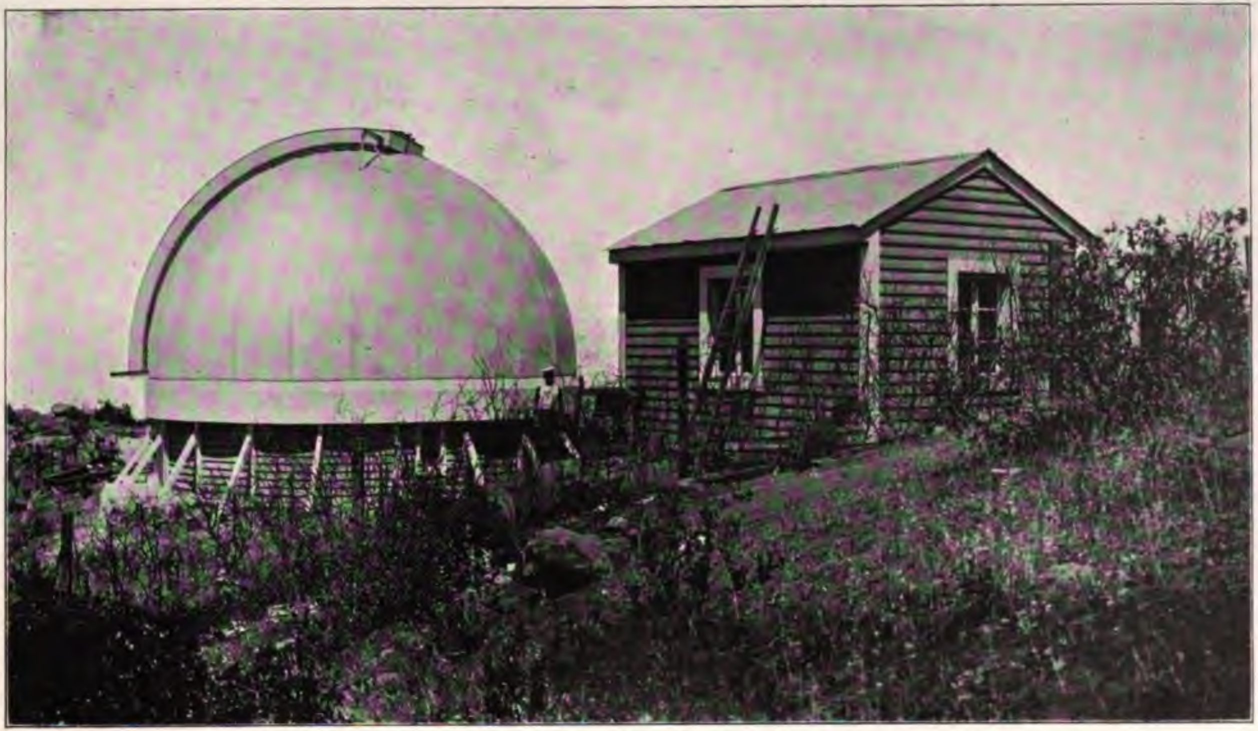
* Lick Astronomical Department of the University of California.



THE OBSERVATORY OF THE D. O. MILLS EXPEDITION.

ELEMENTS OF COMET *a* 1904 (BROOKS).

From observations on April 17th (AITKEN), May 8th (MADDRILL), and May 24th (MADDRILL), we have computed the following set of parabolic elements for this comet:—

$T = 1904$, March 6.9049, G. M. T.

$$\left.\begin{array}{rl} \omega = & 53^\circ\ 27'\ 13''.8 \\ \Omega = & 275\ \ 46\ \ 05.5 \\ i = & 125\ \ 07\ \ 33.1 \end{array}\right\} \text{Mean equinox of 1904.0.}$$

$\log q = 0.432475.$

Residuals (O – C); $\Delta\lambda' \cos\beta' - 1''.0$; $\Delta\beta' + 1''.7$

An ephemeris based on these elements is given in *Lick Observatory Bulletin*, No. 56.

R. G. AITKEN.
J. D. MADDRILL.

May 27, 1904.

COMET *a* 1904 (BROOKS).

This comet was discovered by Dr. W. R. BROOKS on the night of April 16, 1904. The telegram announcing the discovery was received here on Sunday, April 17th, and the comet was observed with the 12-inch telescope the same evening. It was found to be a small object, fairly bright, about ninth magnitude, with a sharp nucleus of about the tenth magnitude, and a short brushy tail extending toward the south.

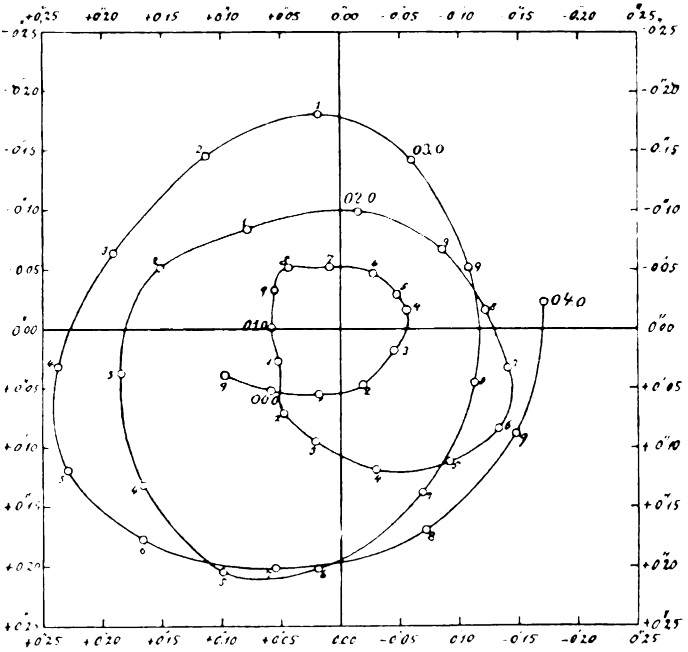
The preliminary orbits that have been computed for this comet show that it has a greater perihelion distance than any one of recent years except GIACOBINI'S comet (*d* 1902), the distance from the Earth at the time of discovery being nearly 2.3 astronomical units. The ephemeris computed from the elements, given on another page, indicates that the comet will remain visible in large telescopes as an evening object throughout the summer and autumn months, the brightness diminishing but slowly.

R. G. AITKEN.

May 27, 1904.

At Mizusawa and at Carloforte there are two observers, so that probably every clear night is utilized; it would appear, then, that the Italian has twice as many clear nights as the Japanese station. The advantage of the Italian weather over that of the other stations is not so great, however, as the numbers would indicate, because there is but one observer at each of the other stations, and when such is the case it is not possible to utilize every favorable night. The relatively small number of observations obtained at Cincinnati is due to the fact that Professor PORTER, the observer, has other duties, and gives only a portion of his time to latitude work.

Provisional results for the latitude work of 1903 have been published recently by Professor ALBRECHT in the *Astronomische Nachrichten,* No. 3945. The amplitude of the polar motion has continued large throughout the year, and has probably reached a maximum. The motion of the Earth's north pole, from 1899.9 to 1904.0, referred to the mean position of the pole for 1900-1901, is represented graphically in the accompanying figure, taken from the number of the *Nachrichten* mentioned above.



It is of interest to note that Professor MILNE's suggestion, made as far back as 1893, that earthquakes may be one of the chief causes of the displacement of the Earth's poles, is yearly receiving statistical evidence for its support. (See article by M. A. DE LAPPARENT in *La Nature* for April 16th, or translation in *Literary Digest* for May 14th.) Some time ago Professor MILNE prepared a table showing the proportionality between the number of violent earthquakes and the amplitude of the polar displacement, from 1895 to 1898. More recently this table has been extended to 1902 by M. CANCANI, with the following result:—

Year.	Number of violent earthquakes.	Polar displacement.
1895	9	0″.55
1896	18	0 .91
1897	44 or 47	1 .07
1898	50	1 .03
1899	27	0 .72
1900	17	0 .32
1901	22	0 .53
1902	29	0 .97

If the numbers of the second column be divided by the corresponding ones of the first column, it will be seen that a rather rough proportionality exists. The evidence is perhaps not yet sufficient to warrant the conclusion that there is here a relation of cause and effect. S. D. T.

The following notes have been taken from recent numbers of *Science*:—

Professor HENRY PERROTIN, director of the Observatory at Nice, died recently at the age of fifty-eight.

The Institute of France has received a bequest from M. JEAN DEBROUSSE, yielding an annual income of about $6,000. A thousand dollars has been appropriated for the publication of a lunar table.

The five-foot equatorial telescope, with Newtonian and Cassegrain mirrors, and many other astronomical and optical instruments belonging to the late Dr. COMMON, are offered for sale by T. A. COMMON, 88 Wigmore Street, London, W.

At a meeting of the National Academy of Sciences held during April Sir WILLIAM HUGGINS and Professor GEORGE H. DARWIN, among others, were elected foreign associates, and the Draper gold medal was presented to Professor GEORGE E. HALE, for his researches in astrophysics.

Miss HELEN SNOW has made a gift of $10,000 as a memorial to GEORGE W. SNOW, her father, to rebuild the horizontal telescope at Yerkes Observatory, which was injured by fire.

The Carnegie Institution has made a grant of $1,500 in continuation of last year's grant aiding the new reduction of PIAZZI's 160,000 star observations. This work, under the direction of Dr. HERMAN S. DAVIS, Gaithersburg, Md., is now well advanced, previous assistance having also been rendered by Miss BRUCE and by the National Academy of Sciences, which continues its aid. A reobservation of all the southern stars of PIAZZI's catalogue by Professor TUCKER has recently been issued as Volume VI of the *Lick Observatory Publications*, and a similar work for all the northern stars by Professor PORTER will be an early publication of the Cincinnati Observatory. Other co-operators, both in this country and in Italy, are expected to complete the entire work in five years or less. It has now been in continuous progress nearly eight years.

Dr. SIDNEY DEAN TOWNLEY, observer in charge of the International Latitude Observatory at Ukiah, has been appointed Lecturer in Astronomy in the University of California.

The Weather Bureau of the U. S. Department of Agriculture has recently published an important bulletin, "The Climatology of California," by Professor ALEXANDER G. MCADIE, Forecast Official in charge of the San Francisco office. This is a quarto volume of 270 pages and contains much valuable information for any one interested in the many climates of this wonderful State. Professor MCADIE begins by discussing the controlling factors in the climate of the Pacific Coast, and these are classified under four heads, as follows:—

1. The movements of the great continental and oceanic pressure areas—the so-called permanent "highs" and "lows," as well as the movements of individual pressure areas.

2. The prevailing drift of the atmosphere in temperate latitudes from west to east.

3. The proximity of the Pacific Ocean, with a mean annual temperature near the coast-line of about 55° F., considered as a great natural conservator of heat.

4. The exceedingly diversified topography of the country for a distance of 200 miles from the coast inland.

The balance of work is given up to discussion and data under the following heads: Climate of North and Central Coast; Climate of Southern Coast; Climatology of the Great Valley; Climate of Santa Clara Valley; Local Climatology; General Precipitation Tables; Snowfall; Precipitation at High Levels; Frost, Fog, Thunderstorms, Earthquakes.

A large amount of tabulated data referring to precipitation, pressure, temperature, and wind is given. As might be expected, an almost endless variety of climates may be found in a State which has over five hundred miles of coast-line, coast ranges of mountains, great inland valleys, great deserts, and a great range of mountains with numerous peaks over 12,000 feet high. The annual precipitation varies from over sixty inches in the north coast counties and high mountain regions to less than two inches in the southeast desert regions. The temperatures vary from the breath of a blast furnace on the desert to the extreme winter cold of the mountain counties.

From the data given for the Lick Observatory we find a mean annual temperature of 52°; mean temperature for January, 40°; for July, 69°; highest temperature (12 years' records), 94°; lowest, 13°. The mean annual precipitation is thirty-two inches, while that of San Jose, only twelve miles distant in a straight line, is but fifteen inches, which furnishes a very good illustration of the effect of local topography upon the amount of rainfall. This is also strikingly illustrated in the short distance, fifty miles, and comparatively level country between San Jose and San Francisco. The rainfall at San Jose is 15 inches; at Menlo Park, 16.5 inches; at San Mateo, 21 inches; and at San Francisco, 23 inches,—an increase of eight inches in fifty miles, and the increase is nearly in proportion to the distance from San Jose.

Mr. McAdie writes very entertainingly concerning the climate of San Francisco. We quote but one paragraph: "When a native of San Francisco is asked which is the coldest month of the year, he is generally at a loss for an answer; and if asked which is the warmest he may say November. This confusion arises from the comparatively small range of temperature. The mean annual temperature as determined from the records of the Weather Bureau for thirty-one years is 56°.1 F. May and November have practically the same temperature. The warmest month is September, 60°.8; the coldest is January, 50°.2. The other months have mean temperatures as follows: February, 52°; March, 54°; April, 55°; May, 57°; June, July, August, 59°; October, 60°; November, 56°; December, 52°." The highest temperature ever recorded in San Francisco was 100°, and the lowest 29°.

The work is illustrated by numerous maps and charts which are a decided help to the reader, and some excellent photographs of fog as seen from Mt. Tamalpais are also inserted.

The book is a highly creditable production, and Mr. McAdie and those who have worked with him are to be congratulated.

S. D. T.

In *The Observatory* for April, Mr. W. F. Denning gives four sketches of a sun-spot of January 22d, showing decided changes during periods of several minutes. He recommends as necessary to successful study, almost continuous observation for a number of hours daily, of some selected spot.

The same number of *The Observatory* publishes a count of *Pleiades* stars by Mr. J. E. Gore. The count was limited to an area of three square degrees on a photograph by the Henry Brothers, and gave the following results:—

Magnitude.	Number.	Totals.	Ratio of Totals.
3	1	1	—
4	2	3	3
5	3	6	2
6	5	11	1.83
7	1	12	1.1
8	12	24	2.0
9	18	42	1.75
10	28	70	1.66

Magnitude.	Number.	Totals.	Ratio of Totals.
11	57	127	1.81
12	113	240	1.9
13	157	397	1.65
14	169	566	1.42
15	267	833	1.47
16	448	1281	1.53

In *A. N.* 3917, Herr H. EBERT accounts for the multiple character of the lines in the spectra of new stars by supposing it to be due to "anomalous refraction" in the layers of vapors of different character and density through which the light passes.

The tenth ordinary meeting of the Royal Society of Edinburgh for the present session was held recently in the Royal Institution, Edinburgh—the Rev. Professor FLINT, vice-president, in the chair.

Dr. HALM, assistant astronomer, Royal Observatory, Edinburgh, read a paper on " Spectroscopic Observations of the Rotation of the Sun." These observations were made at the Royal Observatory during the years 1901-1903. The method employed was that of measuring the displacements of certain Fraunhofer lines in the solar spectrum. If the light from two diametrically opposite points of the solar limb was thrown upon the slit of a spectroscope, the dark absorption-lines of the two spectra showed slight differences in their positions. These differences were caused by the rotation of the Sun round his axis, by which the points of the one limb were moved towards us, and those of the opposite limb from us. But, according to a principle first enunciated by DOPPLER, the wave-lengths of the lines must be shortened in the first case, and lengthened in the other. From the measured displacements it then was easy to compute the corresponding rotational velocities. The apparatus arranged by Dr. HALM for these extremely delicate observations permitted of studying the axial rotation in all solar latitudes. As a general result of his investigation the peculiar decrease of angular velocity from the equator towards the poles, first discovered by CARRINGTON from sun-spot measurements, was confirmed. But the main object of the research was to find out whether the law of rotation was subject to any alterations in the course of an eleven years' sun-spot cycle. The results so far obtained pointed very strongly to the presence of such changes. The values obtained during 1901-1902, at a decided minimum of solar activity, appeared to be materially different from those of 1903, when a new solar cycle was initiated by vigorous displays of spots and eruptions. Thus, to take one instance, a point in 60 degrees solar latitude completed a revolution round the solar axis in 36.2 days in 1901-1902, but such a point only required 29.2 days in 1903 to describe a full circle. Changes of such magnitude in the law of rotation were an entirely novel feature of the complex mechanism of the Sun. Dr. HALM pointed out the necessity of a continuation of his observations, and expressed the hope that other observatories might be induced to take up similar investigations under more favorable atmospheric conditions. —*Extract from the Scotsman.*

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THE SUN'S VELOCITY IN SPACE.

BY W. H. S. MONCK.

A mode of estimating the Sun's velocity in space relative to other stars, and thereby estimating its absolute velocity if that of the other stars can be obtained, has occurred to me which I think worth mentioning. I apply it only to the Sun's motion in Declination. That in Right Ascension could be computed on the same principle, but the computation would be somewhat more laborious, besides which I apprehend that as regards this motion there are some disturbing influences. The North Pole is situated in rather an unconspicuous quarter of the sky, and there is no great constellation within a moderate distance of it which might be expected to affect the motion of a large number of stars; therefore I think the average velocity of the stars measured in the direction of the North Pole is about the average velocity for a point selected at random in the sky. The Sun in like manner does not seem to be situated in a part of the sky to or from which stars may be expected to move with unusual velocity. The average velocity of the stars to or from the Sun is not likely to differ much from the average velocity towards a point selected at random in the sky or towards the North Pole, for the reasons already stated. Hence, if we can compare the Sun's velocity in the direction of the North Pole with the average motion of the stars (whether approaching or receding) in that direction, and also ascertain the average velocity of the stars in the line of sight, we may be able to estimate the actual velocity of the Sun's motion towards the North Pole in miles per second.

It is only the stars with considerable proper motion whose proper motions have been ascertained with accuracy or in whose case we possess anything like a complete list of stars having a motion to or from the North Pole exceeding a definite limit. But if we take, suppose, the one hundred stars having greatest proper motion towards the North Pole and the one hundred stars having greatest proper motion away from it, may we not conclude that the difference between the observed proper motions is due to the motion of the Sun in this direction—the effects of this motion being additive in case of one set of one hundred stars and subtractive in that of the other? This is the principle which I mean to employ. In M. BOSSERT's catalogue, which I think is the largest catalogue of stars with considerable proper motion that I have met with, I found three hundred and twenty-two stars whose annual motion towards the North Pole is not less than 0".10. Possibly this list is incomplete at the lower end, as all catalogues are apt to be; but from the number of stars contained in it which have a proper motion in declination of + 0".10, I think the omission cannot be very numerous. I then took from the same catalogue the three hundred and twenty-two stars which had the greatest proper motion away from the North Pole, and it is on the comparison of these two lists of three hundred and twenty-two stars that I propose to base my estimate of the Sun's velocity in that direction compared with that of an average star. I may, however, remark at the outset that the stars with which I am dealing are not average stars; they are selected on account of their large proper motion. Now, large proper motion may arise from the nearness of the star or from its motion being very nearly perpendicular to the line of sight; but it may also arise—and no doubt in some instances does so—from the star being moving through space with more than the average absolute motion. In this latter case, of course, the effect of the Sun's motion on that of the star will be proportionally less than if it had been moving with the average velocity. If its absolute motion in this direction be double the average velocity, the Sun's motion will only produce half the average proportional effect on it. With this preface I give the results for every tenth star in each series down to the one hundred and sixtieth, and for every twentieth star down to the three hundred and twentieth, beyond which point the catalogue in question does not enable me to proceed.

MOTION IN NORTH POLE DIRECTION.

No. of Star.	Receding.	Approaching.	No. of Star.	Receding.	Approaching.
10	1″.98	0″.95	130	0″.48	0″.23
20	1 .35	0 .76	140	0 .46	0 .22
30	1 .18	0 .61	150	0 .44	0 .21
40	1 .05	0 .45	160	0 .43	0 .20
50	0 .88	0 .39	180	0 .40	0 .18
60	0 .80	0 .36	200	0 .39	0 .16
70	0 .73	0 .34	220	0 .37	0 .15
80	0 .67	0 .30	240	0 .35	0 .13
90	0 .61	0 .29	260	0 .34	0 .12
100	0 .56	0 .26	280	0 .33	0 .11
110	0 .53	0 .25	300	0 .31	0 .10
120	0 .50	0 .24	320	0 .31	0 .10

In the early part of this table the proportion is a little over 2 to 1 (in two instances being slightly under that figure), and it is not until reaching about the two-hundredth star of each series that it gets up to 2½ to 1, from which it continues to rise until it stands at a little over 3 to 1 at the end of the table, where the rise is apparently still in progress. I have already suggested two possible explanations of this fact: First, that the stars in the earlier part of the list (in both series) have on the average greater absolute proper motions, and that the effect of the Sun's motion on them is therefore proportionally less; and, secondly, that M. BOSSERT's catalogue, which I am using, is more deficient in its list of stars having proper motions of between 0″.10 and 0″.15 in North Pole direction, than in stars having proper motions of between 0″.30 and 0″.40. Both causes probably contribute to the result; but, bearing in mind that the increase of the ratio is evidently still in progress where my list terminates, I think that with a longer and more complete list of stars the proportion would not be likely to prove less than 3 to 1. A proportion of 2 to 1, it is hardly necessary to state, indicates that the Sun's motion in North Pole direction is one third of the average velocity of the stars resolved in that direction; while a ratio of 3 to 1 implies that the Sun's velocity in that direction is just one half of the average. The Sun is consequently either a slow-moving star or its motion is directed to a point whose northerly declination falls considerably short of 45°. If we take the average velocity of the stars resolved in this direction (or in any direction assumed at random) to be ten miles per second, the Sun's velocity resolved in the direction of the North Pole will be five miles per second. But I suspect that the general average of star-velocity resolved in a particular direction (irrespective of sign) is greater than ten miles per second, especially as regards such stars as I have been considering.

Another mode of regarding the table suggests that the true proportion between the motions of receding and approaching stars in North Pole direction is at least 3 to 1. I mean, comparing the numbers attached to the approaching and receding stars which have approximately the same apparent proper motion. I have tried this for the receding stars numbered 30, 60, etc., on to 330, in my list, and give the numbers of the approaching stars which most nearly coincide, and also the proper motion of the approaching star whose number is one third of that considered.

No. of Receding Star.	Motion.	No. of Nearest Approaching Star.	Motion.	No. of Approaching Star, = ⅓ of Receding.	Motion.
30	1″.18	7-8	1″.15	10	0″.95
60	0 .80	16	0 .80	20	0 .70
90	0 .61	30	0 .61	30	0 .61
120	0 .50	35	0 .40	40	0 .45
150	0 .44	41	0 .44	50	0 .39
180	0 .40	48-9	0 .40	60	0 .30
210	0 .38	51-5	0 .38	70	0 .34
240	0 .35	62-6	0 .35	80	0 .30
270	0 .33	71-2	0 .33	90	0 .29
300	0 .31	77-8	0 .31	100	0 .26
330	0 .30	79-82	0 .30	110	0 .25

Here there is in every instance more than three times as many stars with a given amount of receding motion as with the same amount of approaching motion, with a single exception in which the number is exactly threefold. Towards the end of the table the number becomes nearly 4 instead of 3. Now, a ratio of 4 to 1 would imply that the Sun's motion in North Pole direction was just the average motion of the stars resolved in that direction. But the present test is not as fair a test as the preceding one. As *real* proper motion diminishes we may expect to find an increasing number of stars at every stage. Hence, the number of stars which can be *brought down* to a particular figure by the effect of the Sun's motion will probably be always less than those that can be *raised to* it by the same effect; and if we take all the stars having a given velocity (irrespective of sign) in the direction of the North Pole of, say, 0".30 per annum, our list will contain a larger number of raised stars than of lowered stars. I do not, therefore, see any valid reason for inferring that the Sun is moving towards the North Pole with a velocity exceeding one half of the average star-motion resolved in that direction. I hope some other member of the Society will take up the subject and arrive at more extensive and satisfactory results. I thought the method in any event worth mentioning, and, with our growing knowledge of the spectroscopic velocities of the stars, I think the prospect of being able to measure the Sun's motion in miles per second cannot be regarded as by any means hopeless.

STAR CATALOGUES.

By Elliott Smith.

The determination of the positions of the stars has long been a matter of much concern to astronomers, and star catalogues have from time to time been issued giving their position with greater or less precision, according to the skill of the observer, the accuracy of his instruments, or the purpose for which the catalogue was made. As a result we have many star catalogues at our disposal, and it may not be out of place to call the attention of A. S. P. readers to a few of these at this time.

Without going into detail it will, no doubt, be sufficient merely to mention the earlier catalogues. They are so inaccurate as to be of no practical value, and they have no connection with modern catalogues, with the exception that the names or numbers assigned to the stars in some of them are in use at the present day. HIPPARCHUS, PTOLEMY, AL-SUFI, and ULUGH BEIGH in order concerned themselves with star places; and the names of TYCHO BRAHE, HALLEY, and HEVELIUS are familiar to students of astronomical literature in this connection. All of the catalogues which they published, with the exception of that of HIPPARCHUS, which has not been preserved, have been compiled and published in the thirteenth volume of the Memoirs of the Royal Astronomical Society, with an introduction giving a description of each.

The middle of the seventeenth century marks the beginning of an epoch of unprecedented activity in the history of catalogue-making, and it may be said to have been formally inaugurated at the founding of the Greenwich Observatory in 1675. This new activity received its impulse from the direct necessity to navigators and explorers of a better knowledge of the positions of the stars and of the motion of the moon and planets.

It was possible for the navigator to determine his latitude at sea with accuracy sufficient for his purpose by simply observing the height of the Pole Star, but the problem of longitude at sea for many years baffled the most expert navigators, and mathematicians were not able to solve it. Handsome prizes were offered by nations whose conquests and colonies in the new world rendered their navigation important, and many methods were suggested. When finally the method of determining longitude by *lunar distances* was proposed, it was found that the knowledge of the positions of the stars and of the motion of the moon and planets was so inaccurate as to render the plan impracticable.

When this report was made to Charles II of England, he at once ordered that an observatory be founded to determine accurately the positions of the fixed stars and the motions of the moon and planets, and in other ways to assist navigation. Systematic observations of the positions of the stars thus begun at Greenwich are being continued by its observers at the present day. Other astronomers, inspired by this new incentive, have been active in meridian observations, so that in the past two centuries such a wealth of catalogues have accumulated that it would be manifestly impossible in so short an article as this to mention more than a small fraction of them. All we can hope to do is to call the attention of the reader to a few of the catalogues found in an observatory library of to-day, of interest from the standpoint of history or of importance to the advancement of the science of astronomy.

The so-called British Catalogue, derived from the observations of FLAMSTEED, the first Astronomer Royal, was published in 1725 in the third volume of the *Historia Celestis.* It was revised and enlarged by BAILY in 1835, and as thus completed contains over 3,300 stars for the epoch 1690. In the column of the catalogue headed "Difference from Bradley" it is interesting to note that in Right Ascension a difference of five minutes of arc is not uncommon, and in Declination the difference in some cases is three minutes.

BRADLEY published no catalogues himself, but while at the Greenwich Observatory he made such accurate observations and such complete records of them that they have been of great value to the science of astronomy. MASON made a catalogue of 389 stars from BRADLEY'S observations, whose places were published in the Nautical Almanac for 1773.

It was left to BESSEL, however, to do the first thorough work upon the observations made by BRADLEY. With the method of reduction which he himself had perfected BESSEL derived the positions of more than three thousand stars from the observations made by BRADLEY from 1750 to 1762. The epoch is 1755, and the catalogue was published in 1818 in BESSEL'S *Fundamenta Astronomiæ.* This catalogue was of much importance to the science of astronomy at the time of its publication. By a comparison with the catalogues of BESSEL'S own time the precession was more accurately determined and the proper motions of many stars became known, making it possible to predict their places for the future with accuracy.

Exact observations are of value at any time, but that their value increases as time goes by is well exemplified by the work of Dr. AUWERS upon the Bradley stars in the latter half of the nineteenth century. With all the refinements of reduction known to modern times and with corrections derived from a thorough investigation of the Bradley instruments, Dr. AUWERS re-reduced the whole mass of BRADLEY'S observations made between 1750 and 1762. The epoch of the catalogue, as in BESSEL'S, is 1755, and it contains 3,222 stars. A comparison of the Bradley positions, thus derived, with observations of the same stars made ninety years later furnished over three thousand proper motions. The work of Dr. AUWERS upon the Bradley stars is published in three volumes: the first contains the determination of the constants of the instruments and the corresponding corrections; the second the results of observation in Right Ascension and zenith distance, and the third the star catalogue. The third volume was published in 1882, the second in 1888, and the first recently came from the publishers under date of 1903.

LACAILLE is the author of three catalogues of stars observed at the Cape of Good Hope. His work attracted considerable popular attention, for he was among the first astronomers to make an expedition to the southern hemisphere for the purpose of observing the southern sky. The first catalogue contains 398 stars for the epoch 1750; the second is a catalogue of 9,766 southern stars for the same epoch; and the third is of 515 zodiacal stars for 1765. The second catalogue was printed about the middle of the nineteenth century at the expense of the British association. The observations for the third catalogue were reduced by BAILY, but not so accurately as the state of the science warranted, and the catalogue has not been of as much service as it might have been.

MAYER'S catalogue of 998 zodiacal stars was published at Göttingen in 1775. It may be found in the fourth volume of the Memoirs of the Royal Astronomical Society. D'AGELET'S catalogue was intended to be a very comprehensive one. It was contemplated to determine the positions of all the stars of the northern hemisphere down to the ninth magnitude. As finally completed the catalogue contains 47,400 stars for the epoch 1800. The positions as given by this catalogue are not very exact, but it has been useful because of being so extensive. The thirty-six fundamental stars of MASKELYNE, fifth Astronomer Royal, were probably the most accurately determined of any up to his time, and they were in general use as reference points by astronomers in the early part of the nineteenth century. It may be of interest to note here that MASKELYNE was the first observer who, in taking a star's transit, divided the seconds into tenths. Observers previous to his time gave simply the nearest second.

The first catalogue of PIAZZI was published in 1803. It contained 7,648 stars, the thirty-six stars of MASKELENE being used as fundamental. Some doubt being thrown upon the Right Ascensions of the Maskelene stars, PIAZZI resolved to make a catalogue founded exclusively upon his own observations. He first constructed a preliminary standard catalogue of 120 stars, published in 1607, to be used as fundamental in the catalogue which followed. This catalogue of 7,646 stars was published in 1814, and at that time was considered of great importance. The observations and reductions were made by PIAZZI himself, and the refraction corrections were derived by him exclusively from his own observations.

All of the Piazzi stars were reobserved by TAYLOR of Madras for the epoch 1835. Most of the southern stars of PIAZZI may be found in the Cordoba General Catalogue for 1875, and the northern Piazzi stars are contained in the *Astronomische Gesellschaft* Catalogue for the same epoch. The reobservations of the Piazzi stars for 1900 completes the list of four epochs for those stars well distributed throughout the century, the southern stars having been observed by Professor TUCKER of the Lick Observatory, and the northern stars by Professor PORTER of the Cincinnati Observatory for the last epoch. A large number of the Piazzi stars have been included in special lists as zodiacal stars and many have been observed as fundamental. The original observations are being reduced anew by Dr. HERMAN S. DAVIS. As a result of all this there is a large amount of material outstanding in regard to the Piazzi stars, and it is expected that a discussion of it will yield results of no little interest and value to astronomy.

Professor AIRY, while Astronomer Royal at the Greenwich Observatory, derived the positions of 4,243 stars from the observations of STEPHEN GROOMBRIDGE for the epoch 1810. The resulting catalogue is of circumpolar stars, and has been of importance for that reason. Those astronomers who have taken up the task of forming a normal system or fundamental catalogue have had constant recourse to the Groombridge catalogue.

BESSEL has been mentioned in connection with the Bradley reductions, but BESSEL himself conducted a valuable and extensive series of observations at the Königsberg Observatory.

Between the years 1821 and 1833 he observed a large proportion of the stars down to the ninth magnitude, quite uniformly distributed in the zone — 15° to + 45° of Declination. The observations were reduced by Professor WEISSE, of Cracow, and published in two volumes at the expense of the St. Petersburg Academy of Science. The first volume contains the stars between — 15° and + 15° of Declination, and the second those between + 15° and + 45°. The two volumes contain over 62,500 stars for the epoch 1825. ARGELANDER continued the observations according to BESSEL'S plan from + 45° to + 80°. OELTZEN reduced ARGELANDER'S observations, and the resulting catalogue in two volumes gives the position of nearly 26,500 stars for the mean epoch 1842.

In connection with star catalogues, however, ARGELANDER will be longest remembered for his work upon the *Bonn Durchmusterung*. By an extensive series of observations he obtained the approximate positions of all the stars to magnitude 9 between + 90° and — 2° of Declination for the epoch 1855. The three volumes in which his work is published contain about 324,200 stars. SCHÖNFELD continued the Durchmusterung to Declination — 23°. His results are published in one volume, which constitutes the fourth volume of the Bonn Durchmusterung. It contains nearly 133,700 stars for the common epoch 1855.

The work of observing the southern stars on the same plan from Declination — 23° to the South Pole yet remained to be done, and the task was undertaken by the Cordoba Observatory. The actual northern boundary at which their work began was Declination — 22°, so that there is a zone of one degree in common between the catalogues of SCHÖNFELD and Cordoba. SCHÖNFELD included all stars to the nine and one half magnitude in his catalogue, while the Cordoba Durchmusterung contains all the stars to magnitude 10 and many even fainter. So far three volumes containing the approximate positions of 480,000 stars between — 22° and — 52° have been published. The epoch is 1875. The work of cataloguing the remaining portion of the southern sky is still in progress at Cordoba. If it is as rich in stars as the portion already observed it is estimated that the Cordoba Durchmusterung completed will contain over 800,000 stars, making a total of considerably more than a million and a quarter stars for the entire sky as catalogued in this great work.

The catalogue in two volumes known as the Gould zones properly represents the results first sought by the founder of the Cordoba Observatory. This catalogue contains the positions of 73,160 stars for 1875 between —23° and —80° of Declination. It includes stars to magnitude 9½, and is in reality a continuation of observations in the southern hemisphere according to plans employed by BESSEL and ARGELANDER in the construction of their catalogues of the northern sky, described above. The observatory was organized by Doctor GOULD, as the National Observatory of the Argentine Republic, and it has been carrying on some extensive pieces of work. of which the Durchmusterung is an example.

While early in the nineteenth century the northern sky was receiving a great deal of attention, the southern sky was not wholly neglected. LACAILLE'S observations in the southern hemisphere have already been mentioned. The Rev. F. FALLOWS, astronomer at the Cape, published in volume CXIV of the *Philosophical Transactions* a catalogue of 273 south circumpolar stars for 1824. BRISBANE'S catalogue of 7,385 stars published in 1835; RÜMKER'S catalogue of some 12,000 stars for 1836; HENDERSON'S Declinations and Right Ascensions of 172 and 174 stars respectively for 1833; JOHNSON'S catalogue of 606 southern stars for 1830; TAYLOR'S general catalogue containing 11,000 stars for 1835, and his catalogue of 97 Principal Fixed Stars for 1845,—all these were among those most in use by astronomers interested in the accurate positions, and in the magnitudes and proper motions of southern stars up to the middle of the last century. Other later catalogues of southern stars that have been in general use and of recognized value to astronomy are the Argentine General Catalogue for 1875, containing all of the brighter stars of the sky within 100 degrees of the South Pole, the catalogue of 1,963 stars by GILLIS, MACLEAR'S catalogue of 1,159 stars for 1860, STONE'S catalogue of 78 south circumpolar stars and his catalogue of 12,441 stars for 1880.

For stars in the northern hemisphere there is such a wealth of observation that to enumerate the catalogues that are of value would require a small volume. We shall therefore mention only a few of those which have been most used by astronomers. Perhaps the catalogues to which we should give our first attention are those which from time to time have been compiled from the Greenwich observations. The Greenwich Twelve-Year Catalogue of 2.156 stars is founded on observations made at Greenwich for the twelve years beginning in 1836. The first six years of observation were reduced to 1840, and the other six years to the epoch 1845. The Six-Year Catalogue of 1,576 stars for 1850, the Seven-Year Catalogue of 2,022 stars for 1860, the new Seven-Year Catalogue of 2,760 stars for 1864, the Nine-Year Catalogue of 2,263 stars for 1872, the Ten-Year Catalogue of 4,059 stars for 1880, the Five-Year Catalogue of 258 fundamental stars for 1890. and a new Ten-Year Catalogue for the same epoch, are monuments to the industry, accuracy, and skill of the Greenwich observers.

In point of accuracy and uniformity in reduction the Pulkova catalogues have not been surpassed. The epoch of their first catalogue is 1845, the Right Ascensions and Declinations being published in separate volumes. The number of stars contained is about 375. Four other catalogues whose epochs are separated by ten-year intervals have been much used. The Pulkova catalogue for 1855 has 3.542 stars; the catalogue for 1865 is published in volume XII of the Pulkova Observations. H. ROMBERG derived a catalogue of 5.634 stars from the Pulkova observations for 1875, and NYREN'S Standard Catalogue of Declinations comes from the same source.

What Greenwich and Pulkova have been to the northern hemisphere, the observatory at the Cape of Good Hope has been to the southern. An enumeration of the epochs of the catalogues which have been published at the Cape will give an idea of the activity of that observatory in catalogue making. 1833. 1840, 1850, 1860, 1880, 1885, and 1890 are epochs of catalogues which have been compiled and published from the Cape Observatory.

Other observatories which may be mentioned as having been especially active in meridian observations are Munich, Oxford, Melbourne, Harvard College, Albany, Washington, Cincinnati, Madison, Berlin, and Paris.

The *Astronomische Gesellschaft* Catalogue is one of the most important of recent date. It will contain, when completed, all the stars to the ninth magnitude included between + 80° and — 23° Declination. For observation the sky was divided into zones of five and ten degrees, different observatories becoming responsible for a larger or smaller zone according to their facilities for carrying on the work of observing. The object in each case was to have the zone assigned to any one observatory as near its zenith as possible to avoid errors in applying refraction corrections. The epoch is 1875 for the northern catalogues, 1900 for the southern.

The catalogue for the northern sky between — 2° and + 80° is all but complete. The second volume containing stars between + 70° and + 75° has not yet been published. It may be of interest to note that two observatories of the United States—Albany and Harvard College—took part in this great work. The first volume of the catalogue for the southern zone recently arrived at the Lick Observatory, and it is hoped that the date of completion of the others may not be far distant.

NEWCOMB and AUWERS are authors of fundamental catalogues most in use at the present time. PORTER and BOSSERT have published standard catalogues of proper motion stars.

The discussion and comparison of star catalogues has become a recognized field of labor for astronomers, and results of no little importance have been derived from it. BOSS, NEWCOMB, AUWERS, CHANDLER and others have concerned themselves in this line of work.

At one time the making of star catalogues was considered the most important branch of astronomy. Researches in the line of what we understand as physical astronomy were looked upon with very little sympathy by the old-line astronomers. We would say in conclusion, however, that the remarkable development which the so-called physical astronomy has undergone in the last half century has only enhanced the importance to the science of an exact knowledge of the positions of the stars, and at present catalogues are being made which aim to give the positions of stars with still greater accuracy. Older catalogues give a clue to the proper motions, so that even though we have a large and ever increasing number of catalogues they are all of use in advancing our knowledge of the sky.

THE LOSS OF LIGHT BY ABSORPTION AND REFLECTION IN THE 36-INCH OBJECTIVE.

By J. H. Moore.

The visual objective of the 36-inch refractor of the Lick Observatory consists of two lenses, a brief description of which, as furnished by Alvan Clark & Sons, is as follows:—

	Radii of Curvature.*		Thickness.	
			Center.	Edge.
	Inches.	Inches.	Inches.	Inches.
Crown No. 1734	$R_1 = +259.52$	$R_2 = +259.52$	1.96	0.60
Flint No. 1588..	$R_3 = -239.59$	$R_4 = -40000.$	0.93	1.65

It will be seen that the total thickness of glass is about three inches. Now, from the table given by Professor Vogel,† for the loss of light in lenses of different thickness, we find that the loss for the visual rays in the 36-inch objective is about twenty-seven per cent and for the photographic rays forty per cent.

In spectrographic work a thin double-concave lens (2.5 inches aperture) is placed one meter within the visual focus to correct for chromatic aberration in the region λ 4500. The loss at this lens is estimated to be about ten or fifteen per cent. The present determination is for the loss of light in the region λ 4500, due to the combined objective and correcting lens.

The Mills spectrograph, mounted upon the large telescope, was directed toward the region of sky 87 North Declination (S. P.) and zero hour-angle, and a spectrogram taken with a slit-width .005 inch and one hundred seconds exposure. The spectrograph, removed from the telescope, was pointed to the same region and with the above slit-width exposures were given ranging from thirty to sixty seconds. A little consideration will show (since the angular aperture of the collimator is equal to that of the 36-inch objective), that the exposure when the spectrograph is off the telescope, which gives the same image density as one hundred seconds exposure when it is on the telescope, represents the percentage of light transmitted by the objective and correcting lens.

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* *Publications of the Lick Observatory*, Vol. III.

† *Astrophysical Journal*, Vol. V, 1897.

To eliminate any error due to variation in the intensity of the sky-light with changing hour-angle of the Sun, the exposures were made in this way: One on telescope, three off telescope; one on telescope, three off telescope; one on telescope.

The effect of diffraction at the slit is to allow light outside the cone of aperture equal to that of the objective to fall upon the collimator-lens when the spectrograph is off the telescope. Any error due to this was shown, by another series of experiments in which a slit of .0006 inch was used, to be very small. In the present experiments the effect of diffraction at the slit is negligible, as a relatively wide slit was employed.

It was possible to detect a two per cent variation in the intensity of the photographic images. From the mean of ten plates an exposure of fifty-one seconds with the spectrograph off the telescope was found to give the same image density as one-hundred-seconds exposure with spectrograph on the telescope. The loss by absorption and reflection of rays λ 4500 at the 36-inch objective and correcting-lens is then forty-nine per cent. Assuming the loss at the correcting-lens to be about ten per cent, this value agrees very well with that calculated above for the 36-inch lens.

Lick Observatory.

THE LOSS OF LIGHT BY DIFFRACTION AT A NARROW SLIT.

By J. H. Moore.

In the design of astronomical slit-spectrographs, where the source of light is in general faint, the question of utilizing as much of the light as possible becomes of fundamental importance. The particular problem for which the instrument is intended will require a certain resolving power and dispersion, which in a prism-spectrograph will correspond to a definite and unavoidable loss of light by absorption and reflection at the prisms and lenses.

To obtain the required purity of spectrum it is necessary to use a slit of small aperture, at which an additional loss occurs, due (1) to the diminished area of the image source, and (2) to diffraction at a narrow slit. This loss at the slit depends upon the linear slit width, while the purity of the spectrum depends only upon the angular aperture of the slit, as seen from the center of the collimator-lens. It is evidently possible, then, to preserve the purity and at the same time avoid some of the loss at the slit, by employing a collimator of sufficient focal length and aperture, and a slit of greater linear width. The importance of this principle in the design of astronomical spectrographs was first pointed out by Professor CAMPBELL.*

The loss of light by diffraction at a narrow slit, for the region of spectrum $\lambda = 1.8\,\mu$ and for slit-widths from 0 to 0.5^{mm}, has been investigated by Professor ABBOT† in his bolometric researches in the infra red spectrum of the Sun. For the region of spectrum and slit-widths employed in line of sight-work no data are available for the loss by diffraction at the slit, and with a view to supplying these the present investigation was undertaken.

In spectrographic work we are interested in photographic intensities. A photographic method of comparing relative intensities from slits of different apertures was therefore selected. The spectrum of a constant source of light was photographed, using a slit-width .002 inch and thirty seconds exposure. This was taken as giving a standard image density. To obtain the relative intensity due to any other slit-width, say .001 inch, a graduated series of exposures was given with this width of slit. An exposure of sixty-six seconds for a slit .001 inch gives the same image density as that of our standard. The photographic intensity due to a slit .001 inch is taken as being proportional to thirty sixty-sixths the photographic intensity due to a slit .002 inch. Any slight error due to the assumption that the density of a photographic image is proportional to the product of the exposure time and intensity of the incident light is not effective in the present experiments.

The Mills spectrograph, mounted upon the 36-inch refractor, was directed toward the region of the sky 90° North

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* W. W. CAMPBELL, The Mills Spectrograph of the Lick Observatory. *Astrophysical Journal*, Vol. VIII, 1898.

† Annals of the Astrophysical Observatory of the Smithsonian Institution, Vol. I, 1900.

Declination and hour-angle six hours away from that of the Sun. The telescope was driven by the clock in order to eliminate the effect of the variation of the plane of polarization of sky-light with reference to the plane of the instrument. In this way a source of light was obtained which was found to be fairly constant when the hour-angle of the Sun was not greater than one hour. To guard against the effect of any variation in the sky-light, the exposures were made in this way (say for a slit .001 inch),—slit .002 inch 30 seconds exposure; slit .001 inch and 63, 64, and 65 seconds exposure, respectively; slit .002 inch and 30 seconds exposure; slit .001 inch and 66, 67, and 68 seconds exposure; slit .002 inch and 30 seconds exposure. It is possible to detect a five per cent variation in the image density by such a method of comparison.

In the following table are given the exposures from the mean of five plates for different slit-widths required to produce the same image density as that from a slit .002 inch and 30 seconds exposure, for the region λ 4500 (the center of the Mills spectrogram). The last column gives the percentage of loss by diffraction for slits of different aperture on the assumption that no light is lost by diffraction at a slit of .004 inch and that the exposure-time varies inversely at the slit-width.

Slit-Width in .001 Inch.	Time of Exposure in Seconds.	Percentage Loss by Diffraction.
4.0	13.0	00
3.5	15.0	00
3.0	17.5	4
2.5	22.0	8
2.0	30.0	13
1.8	34.5	15
1.5	42.5	18
1.4	45.0	19
1.3	49.5	20
1.2	55.0	22
1.0	66.0	24
0.9	77.0	25
0.8	86.5	26
0.7	103.0	28
0.6	134.0	35
0.5	172.0	40

From the above it will be seen that the loss by diffraction increases very rapidly for slits of linear aperture less than

.0007 inch. On the assumption that the light incident upon the slit is parallel, it can be shown that for a slit-width .0007 inch the width of the principal maximum of the diffraction pattern is equal to the diameter of the collimator-lens, (the constants of which in the Mills spectrograph are, focal length $= 722.4^{mm}$, effective aperture $= 38^{mm}$). A further decrease in slit-width will throw part of the principal maximum off of the collimator-lens, causing a rapid decrease in the intensity of the light.

A comparison of ABBOT's results with those given above will show his values for the loss by diffraction at a narrow slit to be relatively much greater than the ones obtained in the present experiments. A little consideration, however, will indicate the cause of this discrepancy (aside from the fact that the wave-length employed by him is four times that used in the present work) is due to the difference in the angular aperture of the collimator in the two instruments. ABBOT used a collimator of angular aperture of about one fifth that of the Mills spectrograph. We should therefore expect the loss by diffraction in his experiments to be relatively much greater than that obtained here.

With the Mills spectrograph, in line of sight-work, a slit of linear aperture .0013 inch is found to give sufficient purity. Now a collimator-lens of twice the diameter and focal length of the present one (neglecting the increased absorption of such a lens) would theoretically enable us to utilize about 2.3 times as much light, as we should then be able to double the slit-width.

On the other hand, the corresponding effective diameter of the collimator-lens would be about three inches. It is very doubtful whether it is advisable to use larger prisms than are employed in the present instrument, for several reasons. To mention only one, such prisms by their greater absorption would reduce greatly the increase of light gained in the above manner.

The substitution of a reflection grating for the prisms may be possible, but here we encounter the difficulty of mounting a reflection-grating so that it cannot move and at the same time not be cramped. Also, since for a reflection-grating there is no position of minimum deviation, a displacement of the grating produces a corresponding shift in the lines of the spectrum.

We may use a Cassegrainian reflector of great relative focal length and a collimator-lens of small linear aperture. However, for average seeing the image would be larger for the instrument of greater focal length, and while we should gain some light, the gain would not be proportionate.

The telescope and spectroscope of greatest efficiency will be those in which the best compromise is made between the various opposing factors; and this will depend to a considerable extent upon the class of work for which the instrument is intended.

Lick Observatory.

VARIABLE STAR NOTES.

By Rose O'Halloran.

V Cassiopeiæ.

When first discovered in December, 1893, by Dr. Anderson, of Edinburgh, *V Cassiopeiæ* was supposed to be a temporary star, but further observation showed that it ranged from about seventh to twelfth magnitude in a period of 229 days. Though in a field thickly strewn with small stars, it may be found without circles by means of two stars of sixth magnitude with which it forms an obtuse triangle. These are numbered 1 and 2 in Flamsteed's catalogue, the variable being about half a degree northeast of the latter, or in R. A. $23^h\ 7^m\ 22^s$, Decl. $+ 59^\circ\ 8'\ 4''$. Near the date of predicted maximum, August 15th, it was observed as follows:—

1904.

July 10. Brighter than any of the closely adjacent stars. Equal to *c*.

July 15 and 17. Equal to *d*, less than *b*.

July 30. Brighter than *b*.

July 31. Ditto. Night very clear.

August 1 and 11. Brighter than *a*, which is the brightest of the numerous stars about one third of a degree to the northeast. *V* seems fully of 7.5 magnitude, but is less than star of 6.8 magnitude to the west.

August 29. Less than *a*, brighter than *b*.
September 2. Ditto.
September 6. Less than *b*, equal to *d*.
September 12. Less than *d*, equal to *e*.
September 18. Equal to *e*. Moonlight.

U Cassiopeiæ.

This variable changes from eighth to fifteenth magnitude in 276 days. The following observations, taken during the last two years, accord with intermediate stages of predicted maxima and minima:—

1902.

September 24. Brighter than the faint star about one minute of an arc north of it. In the accompanying chart it is below it and marked *g*.
October 23. Brighter than *e*, less than *d*.
October 28. Equal to *d*.
October 31. Brighter than *d*, less than *c*.
November 3. Ditto.

1903.

August 16, 23, and 29. Brighter than *e*, less than *d*.
September 2, 8, 13, and 14. About two-tenths magnitude less than *c*.
September 16. Decreased, but still brighter than *d*.
September 29. Brighter than *e*, less than *a*, equals *d*.
October 12. Dimmer than *c*, brighter than *g*.
October 25. Less than *g*.
November 6. Invisible.

1904.

July 12. Brighter than *d*, less than *c*.
July 15. Ditto.
July 31. Equals *f*, less than *c*, brighter than *g*.
August 1. Less than *f*, brighter than *g*.
August 11. Equals *g*.
September 6, 12, and 18. Invisible.

This variable is in the vicinity of *Omicron* in *Cassiopeia*. In the charts, the comparison stars are named alphabetically, according to magnitude.

Vicinity of U Cassiopeiæ Vicinity of V Cassiopeiæ

W Aurigæ.

Occasional observations of this star were taken as follows: 1904—January 4, 12, and 21, February 5. Invisible.

The maximum was predicted for August 15th, but cloudiness delayed observation until the 20th, when it was invisible, though *k* and *l* of 11 and 11.5 magnitude were distinctly seen. The morning was clear and a high power was used. On September 8th it was also invisible, though *k* was discernible in a hazy atmosphere.

X Aquilæ.

As the minimum of *X Aquilæ* was due on July 21, 1904, its vicinity was observed with a four-inch telescope, in which stars of twelfth magnitude are discernible in very clear weather. Seventeen observations were taken from the 11th of June to the 12th of September, but it was invisible. Several of the evenings were very clear. It may have decreased below twelfth magnitude.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1904.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter,	Sept.	2,	6^h 58^m	P.M.	Last Quarter,	Oct.	2,	5^h 52^m	A.M.
New Moon,	"	9,	12 43	P.M.	New Moon,	"	8,	9 25	P.M.
First Quarter,	"	16,	7 13	A.M.	First Quarter,	"	15,	9 54	P.M.
Full Moon,	"	24,	9 50	A.M.	Full Moon,	"	24,	2 56	A.M.
					Last Quarter,	"	31,	3 13	P.M.

The autumnal equinox, the time when the Sun crosses the Equator from north to south, occurs September 23d, 4 A.M., Pacific time.

The second of the two eclipses of the year occurred September 9th. It was a total eclipse of the Sun, but it was not visible from any part of the United States. The line of totality ran across the Pacific from a position eastward of the Caroline Islands to the western coast of South America. Unfortunately there are practically no good observing stations along the line as seen on ordinary maps. This is doubly unfortunate as the duration of totality is a long one, $6^{m}\ 24^{s}$, and this would give an unusually good opportunity for observations of the outer portions of the corona, while the brighter inner parts are behind the Moon's disc, more than in an eclipse of shorter duration, the apparent disc of the Moon being larger than that of the Sun by an amount unusual at a time of eclipse. The duration of totality was about the same for the eclipse of May 17, 1901, but the average duration in total solar eclipses is only about half as great.

Mercury on September 1st is an evening star, setting about half an hour after sunset. It rapidly nears the Sun and passes inferior conjunction on September 15th. From that time until the last night in October it is a morning star. It reaches greatest west elongation, 17° 54′, on October 1st, and then rises an hour and a half before sunrise. Until the middle of October the interval is an hour or more. The period is therefore a good one for seeing the planet as a morning star. The planet will be quite near the Moon on the evening of October 7th.

Venus is now an evening star, and has moved far enough away from the Sun to be seen in the evening twilight soon after sunset. It sets about forty minutes after the Sun on September 1st, an hour on October 1st, and an hour and a half on November 1st. It passes about 3° north of *Spica,* α *Virginis* on September 23d. There is a close approach to the Moon on the evening of September 10th, the day after New Moon.

Mars is a morning star, slowly falling behind the Sun in their common eastward motion. It rises a little after 3 A.M. on September 1st, and at a little after 2 A.M. on October 31st. It moves 36° eastward and 13° southward from *Cancer* into *Leo,* and on September 28th passes about 1° north of *Regulus,* α *Leonis.* Its actual distance from the Earth has begun to diminish, and there is a consequent increase in brightness, but it does not amount to much as yet. However, there will be no difficulty in seeing it, as it will be brighter than a second-magnitude star.

Jupiter rises at 8:40 P.M. on September 1st, at 6:36 on October 1st, and at 4:20 on November 1st. It reaches opposition with the Sun on the afternoon of October 18th. It moves about 6° westward and nearly 3° southward in the constellation *Pisces.* There are few bright stars in that region of the sky. The late autumn and early winter evenings will give a fine opportunity for observations of this planet.

Saturn is also in good position for evening observation. It is on the southern meridian at 10:33 P.M. on September 1st, and at 6:27 P.M. on November 1st, and sets about five hours later than its time of meridian passage. It moves westward about 2° in the eastern part of *Capricorn* until October 19th, and then begins to move slowly eastward.

Uranus is in the southwestern sky in the evening. It is on the meridian at 7 P.M. on September 1st, and at 3:06 P.M. on November 1st, and sets about four and one half hours later. On account of its faintness it cannot be seen with the naked eye except when it is at a considerable distance from the horizon. It is stationary on September 4th, and then begins to move slowly eastward, moving about 1° 30′ up to the end of October. It is west and a little north of the group known as "the milk dipper," in *Sagittarius,* but no bright stars are very near.

Neptune is in *Gemini.* Toward the end of October it rises about 9 P.M.

During the early morning of October 27th the Moon will pass over the *Hyades* group in *Taurus,* and a number of the brighter stars will be occulted.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1904.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

New Moon,	Nov. 7,	$7^h\ 37^m$	A.M.	New Moon,	Dec. 6,	$7^h\ 46^m$	P.M.
First Quarter,	" 14,	4 35	P.M.	First Quarter,	" 14,	2 7	P.M.
Full Moon,	" 22,	7 12	P.M.	Full Moon,	" 22,	10 1	A.M.
Last Quarter,	" 29,	11 38	P.M.	Last Quarter,	" 29,	7 46	A.M.

The Sun reaches the winter solstice and winter begins December 21st, 10 P.M., Pacific time.

The Earth is in perihelion December 31st, 9 P.M., Pacific time.

Mercury passes superior conjunction with the Sun on the morning of October 31st, and remains an evening star until the morning of December 31st. It reaches its greatest eastern elongation, 20° 30′, on the morning of December 13th, and then sets at a little less than an hour and a half after sunset. For a week or more before and after that date it may be seen in the evening twilight; but the duration of its visibility is not as great as it is when the greatest eastern elongation comes in the spring months. Early in December, before it comes to greatest elongation, it will be in the most southern part of its orbit. This will cause the interval between sunset and the setting of the planet to be smaller than usual, and retard the time of its becoming visible. Also the interval between greatest elongation and inferior conjunction is only seventeen days. The corresponding interval for the preceding period was ten days longer. In December the planet is in the part of its orbit nearest the Sun, passing perihelion only a few days before coming to conjunction, and consequently it moves much faster.

Venus is also an evening star, and the interval between the setting of the Sun and of the planet increases rapidly. On November 1st it is about an hour and a half, on December 31st it is nearly three hours and a half, and the planet is nearly out to its greatest eastern elongation. The reason for the comparatively rapid increase now, as compared with the slow increase of interval for some months after superior conjunction, is this—up to about December 1st the planet was south of the Sun; after that date it begins to be more and more north of the Sun. This causes the rapid increase in interval from sunset to the setting of the planet. The eastward motion of the planet among the stars has been comparatively uniform. On November 16th, 10 P.M., it passes 1° 28′ south of *Uranus*, and on the morning of December 28th it is 0° 48′ south of *Saturn*. At the beginning of November it is about 4° north of *Antares*, *α Scorpii*.

Mars is drawing farther away from the Sun and rising earlier; on November 1st it rises at 2:21 A.M. and on December 31st at 1:16 A.M. It moves about 32° eastward and 13° southward from *Leo* into *Virgo*. On December 27th it is 4° north of *Spica*, *α Virginis*. On the morning of December 2d there is a very close approach to the Moon, and an occultation in some places. On November 29th the planet reaches its greatest distance in miles from the Sun, although it is now nearer the earth by a considerable amount than it was at the time of its greatest distance, early in July. In consequence of the diminished distance from the Earth, more than counterbalancing the increase of distance from the Sun, *Mars* at the end of December will be about two and one third times as bright as it was on July 1st. This is an increase of almost exactly one magnitude, and at the end of the year it will be about as bright as a first-magnitude star like *Spica.*

Jupiter is in fine position for evening observation. It passed opposition with the Sun on October 18th. and is now well above the horizon at sunset. It crosses the meridian at 10:46 P.M. on November 1st, and at 6:39 P.M. on December 31st. It sets rather more than six hours after meridian transit. Until about the middle of December the planet is moving westward in the constellation *Pisces.* It then begins to move eastward; but the whole motion during the two months is less than 3°.

Saturn is still in good position for observation in the western sky in the evening, although it draws rather close to the Sun toward the end of the year. It sets at 11:26 P.M. on November 1st and at 7:50 P.M. on December 31st, crossing the meridian about five hours earlier. It is in the eastern part of *Capricorn* and moves about 4° eastward during the two months.

Uranus is too near the Sun to be seen. It is in conjunction on December 22d, and changes from an evening to a morning star. It is still in *Sagittarius* and moves about 4° eastward.

Neptune is in opposition with the Sun on the evening of December 28th.

The first-magnitude star *Aldebaran*, α *Tauri*, will be occulted by the Moon on the evening of December 20th. The occultation will be visible from most parts of the United States.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

THE DOUBLE STAR O Σ 21.

In July of the present year I found that the 6.3-magnitude star, 6½^m preceding *φ Andromedæ* and 7′ north of it, is a close double star. Measures on four nights give the following result:—

1904.54 361°.0 0″.22 6.2-8.0 magnitudes.

In view of the past history of this star, this discovery is both interesting and surprising.

It was first noted as a double star by OTTO STRUVE in 1845, and was measured by him on four nights, between 1845 and 1851, with accordant results, the mean of which is: 170°.6 0″.56 6.9-8.2 magnitudes. This pair is known as O Σ 21, and was measured in 1884 by both SEABROKE and SMITH with results in fair agreement with STRUVE's; and again on one night in 1898 by HUSSEY, who obtained 160°.7 and 0″.74.

If this were the complete micrometric history of the star it would be very interesting, because of the great change apparently observed between 1898 and 1904; but in view of the meagerness of the observations there would be nothing very surprising about it.

But from the account given by Professor HUSSEY in his "Observations of the Pulkowa Double Stars" (*Lick Observatory Publications,* vol. V, p. 39), it appears that DEMBOWSKI could not measure this pair in 1864, 1865 or 1878; that MÄDLER, in 1845, measured a seventh-magnitude star a little preceding this star, obtaining 45°.1 0″.97, and supposed he was measuring O Σ 21; that BURNHAM measured MÄDLER's pair in 1878, 1879, and 1891, and expressly stated that in the two former years he could not find any other pair in that vicinity; and finally, that

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* Lick Astronomical Department of the University of California.

Hussey himself was unable to see O Σ 21 double on many nights in 1898 and 1900 (also in 1902, see *L. O. Bulletin*, No. 40), even with the 36-inch telescope. As Professor Hussey points out, it seems impossible to reconcile his positive measure with the subsequent negative results, and equally dfficult to explain the agreement of his measure with Otto Struve's if some other pair was observed by either by mistake.

My measures only add to the puzzle, for it does not seem possible that the new companion can be identical either with the one measured by Otto Struve or with the one seen by Professor Hussey. The explanation must be left to the future.

September 2, 1904. R. G. Aitken.

UNSUCCESSFUL SEARCH FOR PERIODIC COMETS.

It is generally best to keep silent about searches of any kind that result unsuccessfully, but occasionally it happens that failure has a value only second to success. This seems to apply with special force to the search for periodic comets whose orbits are supposed to be well known, and whose position in the sky, according to the predicted motion, is favorable for observation. I therefore wish to place on record the fact that I have looked for every periodic comet predicted to return to the neighborhood of the earth during the past two years, using the 36-inch telescope under the best obtainable conditions. With the exception of Brooks's comet, 1889 V, 1896 VI, which was found close to its predicted place on the first night's search, none of the comets looked for have been seen. Some, like Perrine's comet last year, and Temple's comet (1873 II) this year were so nearly in line with the Sun that their position could hardly be regarded as favorable. Others, like Giacobini's comet last year and Wolf's comet the present year, were not far from opposition at the time of search, and the failure to see them must be due either to the extreme faintness of the objects or to the uncertainty of the predicted positons. It is not feasible with a telescope as large as the 36-inch to examine a very large sky area for a faint comet. My practice has been to chart the predicted position of the comet and to examine minutely with a low-power eye-piece about a square degree of the sky about this position; then, more rapidly, several more square degrees along the line of predicted motion. R. G. Aitken.

September 5, 1904.

ONE HUNDRED AND FIFTY-FIVE NEW DOUBLE STARS.

Lick Observatory Bulletin, No. 61, contains detailed measures of one hundred and fifty-five new double stars, numbered, in continuation of those previously published, A 646 to A 800.

More than one half of these pairs were discovered with the 12-inch telescope, but nearly all of the measures were made with the 36-inch.

Only two pairs whose components are separated by more that 5″ are included in this list, 116 pairs, or 75 per cent of the whole number, are separated by less than 2″, and 13 pairs are closer than 0″.25. The list includes two naked-eye stars, and closer components to five pairs catalogued by previous observers, viz.: Σ 1506, Σ 2588, h 1541, h 2027, and *Espin* (unnumbered).

The following table shows the classification by distance between the components of the 800 A. stars now published:—

Distance.	No. of Stars.	Per cent.
0″.00 to 0″.25	58	7.3
0 .26 " 0 .50	162	20.2
0 .51 " 1 .00	169	21.1
1 .01 " 2 .00	193	24.1
2 .01 " 5 .00	210	26.3
5 .01 " 5 .27	8	1.0

September, 1904.

R. G. AITKEN.

THE CROCKER ECLIPSE EXPEDITIONS IN 1905.

(The following announcement by Director CAMPBELL was made in *Lick Observatory Bulletin*, No. 59.)

The next observable total solar eclipse occurs on August 30, 1905. It is remarkably well situated, and is looked forward to with great interest. The shadow path begins at sunrise south of Hudson Bay, enters the Atlantic Ocean a short distance north of Newfoundland, crosses northeastern Spain, northeastern Algiers, and northern Tunis, passes centrally over Assuan on the Nile, and ends at sunset in northeastern Arabia. The durations on the coast of Labrador, in Spain, and at Assuan are two and one half, three and three fourths, and two and three fifths minutes, respectively.

The interval of two hours and one half between the instants of totality in Labrador and Egypt offers an unusual advantage for obtaining large-scale photographs of the solar corona, with a view to determining changes in the forms and positions of the delicate details of structure. The opportunity to bring the search for intermercurial planets to a satisfactory conclusion is also exceedingly promising. Should a new planet be observed at three stations, the interest attaching to its discovery would be heightened by the fact that its approximate orbit could be determined at once. If no planets are revealed, on good photographs, the negative results would be scarcely less valuable though certainly less interesting than positive results, and the intramercurial planet question would cease to be a pressing eclipse problem.

In Spain, the high altitude of the eclipsed Sun, and the promising weather conditions, are also very favorable for polarigraphic, spectrographic, and other investigations.

An important element in the success of eclipse observations consists in the opportunity to prepare the instrumental equipment, and the program and methods of observation, well in advance, in order that critical tests may be applied to them before the expeditions depart for their observing stations.

It is a pleasure to announce that Mr. WILLIAM H. CROCKER has again shown his interest in the science of astronomy by offering to meet the expenses of expeditions to be sent from the Lick Observatory to Labrador, Spain, and Egypt, to secure observations of the 1905 eclipse.

The provisional program for the three stations is, in the main, as follows:—

LABRADOR.

A photographic search for intramercurial planets in a region of the sky 8½° wide, extending in the direction of the solar equator from 4° below the Sun to 15° above it.

The photography of the corona by means of a camera of five inches aperture and forty feet focus, of the form first used by Professor SCHAEBERLE at the eclipse of 1893.

SPAIN.

A photographic intramercurial search covering a region 9¼° wide, extending in the direction of the solar equator from 14° below to 14° above the Sun.

The photography of the solar corona with a camera of five inches aperture and forty feet focus.

A study of the polarized light in the corona.

The use of spectrographs provided with moving plate-holders to obtain a continuous record of changes in the spectrum of the Sun's edge at the time of second and third contacts; of spectrographs for determining the wave-length of the green coronal bright line, and, if possible, the wave-lengths of the bright and dark lines in the isolated spectrum of the Sun's edge, as nearly as possible at the time when the dark lines give way to bright ones, and *vice versa*; and of a spectrograph for recording the general spectrum of the corona.

EGYPT.

A photographic intramercurial search 8½°, extending in the direction of the solar equator from 4° below to 15° above the Sun.

The photography of the solar corona with a camera of five inches aperture and forty feet focus.

The photography of the general spectrum of the corona.

THE PUBLICATION OF THE CROSSLEY REFLECTOR PHOTOGRAPHS OF NEBULÆ AND STAR-CLUSTERS.

(Announcement by Director CAMPBELL in *Lick Observatory Bulletin*, No. 59.)

The late Director KEELER's observing program for the Crossley Reflector included the photography of about one hundred of the principal nebulæ and star clusters. The portions of his program available for observation in our clear summer weather were practically complete at the time of his death; but those in position during the cloudy winter months, forming nearly a half of the whole, were incomplete. After the lamented death of Professor KEELER, Assistant Astronomer PERRINE, in charge of the Crossley Reflector, made it his first duty to complete the observing program. This was accomplished in September, 1903. The importance of prompt publication of this invaluable series of photographs has been fully realized, but difficulties, both technical and financial, have existed. Plans have recently been completed whereby it is hoped to issue, within the coming half-year, a volume of the *Lick Observatory Pub-*

lications, to contain high-class reproductions of seventy-two of the principal subjects, as well as a list of several hundred new nebulæ incidentally recorded on the negatives.

The purpose of this announcement is that suitable acknowledgment may be made concerning the generosity of the following friends of the Lick Observatory, who have provided funds to meet such portions of the expenses of reproducing the photographs as cannot be supplied from printing funds appropriated by the State of California:—

Mr. WILLIAM ALVORD,
Mr. E. J. DE SABLA,
Mr. JOHN B. JACKSON,
Miss MATILDA H. SMITH,
Miss JENNIE SMITH,
Mr. BENJAMIN THAW,
Mr. ROBERT BRUCE,
Mrs. PHŒBE A. HEARST,
Mr. E. J. MOLERA,
Mr. F. M. SMITH,
Mrs. WILLIAM THAW,
Mr. ROBERT J. TOBIN.

THE SUN'S CORONA.

Professor SVANTE AUGUST ARRHENIUS, of the chair of physics in the University of Stockholm, Sweden, who spent two months during the summer at the University of California, is the author of *Lick Observatory Bulletin*, No. 58, which gives his observations on the physical nature of the Sun's corona as observed at total solar eclipse. The *Bulletin* is a notable contribution to astronomical literature in that it reconciles hitherto conflicting scientific opinion concerning an important phase of the Sun's constitution. An abstract of the *Bulletin* is as follows:—

This paper was written by Professor ARRHENIUS during his recent visit on Mount Hamilton for the purpose of harmonizing the apparently conflicting results as to the sources of the coronal light obtained by the Crocker expeditions from the Lick Observatory and by the Smithsonian Institution observations. Astronomers CAMPBELL and PERRINE held the view that the light of the inner portions of the corona is due to radiation from minute dust particles maintained at a temperature of incandescence by the enormous heat of the adjacent solar surface, and that the light from the outer corona is composed mainly of sunlight reflected and diffracted by the colder dust particles composing this part of the corona. The Lick Observatory conclusions were based upon the character of the spectrum of the corona.

The Smithsonian observers measured the quantity of heat received from the corona and were surprised to find that, even in the immediate proximity of the solar surface, the effective temperature was substantially that of the room in which they were observing. They therefore held the view that the main source of light from the corona is not the incandescence of its particles, but that the radiations are in the nature of an electrical discharge. ARRHENIUS has succeeded in harmonizing all the results of observation by showing that the particles in the region observed must be at a temperature of about 8,000° Fahrenheit, and therefore must be radiating light by virtue of their incandescence, but that the particles are so few and far between that the effective temperature observed is not the temperature of the particles themselves, but is the average temperature for the incandescent particles and the cold background of space upon which these particles are seen, here and there, in projection. The total area of the background covered by the particles in projection is but a minute fraction of its whole area. The spectroscope and thermometric observations are completely harmonized by assuming that, in the part of the corona observed, there is but one minute dust particle for each fifteen cubic yards of space.

ARRHENIUS has, on this supposition, computed the total mass of the corona, and has found its most probable value 25,000,000 tons. This is approximately the same as that of a cube of granite whose sides are 670 feet in length. The quantity of matter involved in the corona is thus shown to be exceedingly slight, considering that it occupies a space whose dimensions in every direction amount to several millions of miles.

W. W. CAMPBELL.

ON SOME RESULTS OBTAINED BY THE D. O. MILLS EXPEDITION TO THE SOUTHERN HEMISPHERE.*

In the extended program for determining the velocity of the solar system through space by means of the radial velocities of the stars, which has been in progress at the Lick Observatory for seven years, the need had long been felt for extending the scope of the work so as to cover the entire sky. For a full and rigorous solution of the problem it seemed absolutely imperative that the neglected portion of the southern sky within 60° of the South Pole be included. The generosity of Mr. D. O. MILLS made it possible to supply this deficiency. As is well known, the equipment sent to South America consisted of a powerful three-prism spectrograph attached to a 37-inch reflector of the Cassegrainian form. The Observatory is situated on the summit of Cerro San Cristobal in the city of Santiago, Chile, and definite work on the program was commenced on September 11, 1903, by Astronomer W. H. WRIGHT and Dr. H. K. PALMER. Up to June 1, 1904, three hundred and eight successful spectrograms had been secured.

One of the most interesting "by-products" of the spectrographic determination of the solar velocity, as carried out at Lick Observatory, has been the discovery that at least one in every seven or eight of the brighter stars are spectroscopic binaries. Similar results are being secured at the Southern Station, and in *Lick Observatory Bulletin*, No. 60, Mr. WRIGHT announces the binary character of five stars: *β Doradus*, *W Velorum*, *λ Carinal*, *κ Pavonis*, and *τ Sagittarii*.

Mr. WRIGHT has also succeeded in measuring the difference in radial velocity of the components of the visual binary *α Centauri*. From a combination of these data with the visual elements, as is well known, the parallax can be obtained with great accuracy and without the assumptions as to the great distance of the comparison-stars used which must be made in heliometrically determined parallaxes.

The values secured are:—

$$\pi = 0''.76 \pm 0''.03$$
$$\alpha = 3.46 \pm .10$$
$$m_1 + m = 1.9$$

GILL and ELKINS's value from heliometer observations was 0''.75 ± 0''.01, relative to the comparison-stars used, which were of average magnitude 7.6.

H. D. CURTIS.

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* Abstract of *Lick Observatory Bulletin*, No. 60.

GENERAL NOTES.

The *Astronomical Journal* of May 20th contains an article on the orbit of the fifth satellite of *Jupiter*, by EMILY ELIZABETH DOBBIN. The elements of Dr. COHN have been corrected by the observations of Professor BARNARD made subequent to 1894. "The most noticeable feature of these results is the smallness of the eccentricity, as compared with that obtained by Dr. COHN and M. TISSERAND. Whether the change is real, and denotes a progressive perturbation which will end in reducing the ellipse to a perfect circle, or is an accidental one, can only be decided after another decade or more."

The computer has used only the observations of Professor BARNARD and justifies this course by the statement: "Only the observations of Professor BARNARD are considered in this paper, though I am aware of the extensive labors of Dr. R. G. AITKEN of the Lick Observatory. The homogeneity gained by excluding such observations seems to more than balance any loss in quantity."

This reasoning seems a bit odd to some of us who have been "brought up" differently. The procedure amounts, practically, to rejecting all observations except Professor BARNARD'S. There is some question as to what the author means by homogeneity, and it is to be regretted that further explanation is not given. Dr. AITKEN'S observations of the Fifth Satellite were made by connecting it with one or more of the other satellites, while Professor BARNARD'S were, I believe, made by measuring the distance of the satellite from *Jupiter's* limb. Here are two quite different methods of observing and in order to make the two series comparable it might be necessary to employ reduction factors whose exact values are not known. It is to be inferred, however, from the sentence quoted above that it would have been possible to include other observations.

Beginners usually find it very easy to reject observations and most teachers of the Method of Least Squares have to spend considerable time trying to teach their students that observations should never be rejected except for good and sufficient reasons. These can be defined in a general way, but as far as my experience goes "lack of homogeneity" has never been accepted as a good and sufficient reason. If there is a difference between the results of two series of observations there is but one explanation, namely, that either one or both of the series is affected by systematic errors. To be sure, smaller probable errors and nicer looking results may usually be obtained by using only one series of observations, but if two or more series be employed the probabilities are that the results will be nearer the *truth*. To obtain as nearly the truth as possible should be the aim of every scientific investigation. In the present case the aim seems to have been to satisfy as nearly as possible one man's observations. Instead of rejecting other observations the computer should welcome them with open arms, and if the number becomes unwieldy it would be better, in general, to reject some of each rather than all of one. An excellent example of the benefit to be derived from combining the observations made with different instruments has been brought forth recently by Mr. HINKS, in his determination of the solar parallax from observations of *Eros*, reference to which may be found on page 225. S. D. T.

The *Astrophysical Journal* for June contains an interesting article by Professor LANGLEY, on a possible variation of the solar radiation and its probable effect on terrestrial temperatures. By way of introduction Professor LANGLEY states: "The purpose of the present communication is primarily to discuss the validity of a surmise we may entertain, founded on observations here, as to certain possible changes in the solar constant. There is especially discussed a possible falling off of solar radiation about the close of March, 1903, as indicated by certain recent values of solar radiation computed from observations here, and compared with actually observed temperatures for eighty-nine stations of the North Temperate Zone."

Without going into the details of the observations we quote Professor LANGLEY's summary and conclusion: "A series of determinations of the solar radiation outside the atmosphere (the solar constant), extending from October, 1902, to March, 1904, has been made at the Smithsonian Astrophysical Observatory under the writer's direction.

"Care has been exercised to determine all known sources of error which could seriously affect the values relatively to each other, and principally the varying absorption of the Earth's atmosphere. Though uncertainty must ever remain as to the absorption of this atmosphere, different kinds of evidence agree in supporting the accuracy of the estimates made of it and of the conclusions deduced from them.

"The effects due to this absorption having been allowed for, the inference from these observations appears to be that the solar radiation itself fell off about 10 per cent, beginning at the close of March, 1903. I do not assert this without qualification, but if such a change in solar radiation did actually occur, a decrease of temperature on the Earth, which might be indefinitely less than 7°.5 C., ought to have followed it.

"On comparing the observed temperatures of 89 stations, distributed over the North Temperate Zone, with the mean temperatures of the same stations for many previous years, it is found that an average decrease of temperature of over 2° C. actually did follow the possible fall of the solar radiation, while the temperature continued low during the remainder of the year. Stations remote from the retarding influence of the oceans show a much greater variation than that of the general mean.

"While it is difficult to conceive what influence, not solar, could have produced this rapid and *simultaneous* reduction of temperatures over the whole North Temperate Zone, and continued operative for so long a period, the evidence of solar variation cannot be said to be conclusive. Nevertheless, such a conclusion seems not an unreasonable inference from the data now at hand, and a continuation of these bolographic studies of solar radiation is of increasing interest, in view of their possible aid in forecasting terrestrial climatic changes, conceivably due to solar ones."

In the *Monthly Notices* for June Mr. HINKS, of Cambridge Observatory, presents an interesting article on the determination of the solar parallax from a reduction of photographs of *Eros*. Mr. HINKS developed some methods of reduction, and in order to test their practicability secured from several observatories measurements of all the plates taken between November 7th and 15th, which is only a small part of the interval over which photographs of *Eros* were taken. The measurements were contributed by the observatories at Algiers, Cambridge, Minneapolis, Mount Hamilton, Northfield, Oxford, Paris, San Fernando, and Tacubaya, and a total of 295 plates are discussed in the paper.

The value of the parallax obtained is 8″.7966, which is in very close agreement with the value used in the almanacs.

Almost all of the measurements were found to be affected by systematic errors of some sort, many of which it would have been impossible to find had the measurements made at each observatory been discussed separately. This is an excellent illustration of the point which I have attempted to bring out in the first one of these notes,—that, in general, it is always better if possible to discuss together the observations made with various instruments rather than to take alone those made by one man with one instrument to the exclusion of all others.

S. D. T.

The following notes have been taken from recent numbers of *Science*:—

Dr. MICHELERHANA, of the Observatory of Milan, has been made director of the observatory at Bologna.

Mr. H. C. RUSSELL, government astronomer of New South Wales, will retire at the end of the present year, after a service of forty-six years.

Professor SIMON NEWCOMB has been elected corresponding member of the Berlin Academy of Sciences.

M. HAMY, assistant astronomer in the Paris Observatory, has been appointed astronomer in the room of the late M. CALLANDREAU.

Dr. HANS BATTERMAN, astronomer at the Berlin Observatory, has been made director of the observatory and professor of astronomy at Königsberg.

The following interesting announcement is taken from *Science*:—

With the aid of a grant of $10,000 from the Carnegie Institution, for use during the current year, the Yerkes Observatory of the University of Chicago has sent an expedition to Mt. Wilson (5,886 feet), near Pasadena, California, for the purpose of making special investigations of the Sun. The principal instrument to be erected on the mountain is the Snow horizontal telescope, recently constructed in the instrument and optical shops of the Yerkes Observatory as the result of a gift from Miss HELEN SNOW, of Chicago. This telescope is a cœlostat reflector, the cœlostat mirror having a diameter of thirty inches. A second plane mirror, twenty-four inches in diameter, reflects the beam north from the cœlostat to either one of two concave mirrors, each of 24-inch aperture. One of these concave mirrors, of about sixty feet focal length, is to be used in conjunction with a solar spectrograph of five inches aperture and thirteen feet focal length; a spectroheliograph of seven inches aperture, resembling the Rumford spectroheliograph of the Yerkes Observatory; and a stellar spectrograph provided with a large concave grating and mounted in a constant-temperature laboratory. It is hoped that it will be possible with this stellar spectrograph to photograph the spectra of a few of the brightest stars. For fainter stars the spectrograph is to be provided with several prisms. for use singly or in combination. The second concave mirror of the cœlostat reflector is designed to give a large focal image of the Sun, especially adapted for investigations with a powerful spectroheliograph and for spectroscopic studies of sun-spots and other solar phenomena. The focal length of this mirror is about 145 feet, so that it will give a solar image about sixteen inches in diameter. The spectroheliograph for use with this large solar image is to be seven inches aperture and thirty feet focal length. For the present, until a suitable grating can be obtained, the dispersive train of this instrument will consist of three prisms of 45° refracting angle, used in conjunction with a plane mirror, so as to give a total deviation of 180°. The motion of the solar image, of which a zone about four inches wide can be photographed with the spectroheliograph, will be produced by rotating the concave mirror about a vertical axis by means of a driving-clock. A second driving-clock, so controlled as to be synchronous with the first, will cause the photographic plate to move behind the second slit. Three slits will be provided at this point, so as to permit photographs to be taken simultaneously through as many different lines of the spectra. It is hoped that this spectroheliograph will prove to be well suited for use with some of the narrower dark lines of the solar spectrum.

The work of the expedition is under the immediate direction of Professor GEORGE E. HALE, director of the Yerkes Observatory. During his absence Professor E. B. FROST will be in immediate charge of the Yerkes Observatory, with the title of acting director. Professor FROST will also be the managing editor of the *Astrophysical Journal.* Mr. FERDINAND ELLERMAN and Mr. WALTER S. ADAMS will be associated with Professor HALE in the work on Mt. Wilson.

Professor S. W. RITCHEY, superintendent of instrument construction at the Yerkes Observatory, will be in charge of an instrument-shop which is being fitted up for the expedition to Pasadena.

The following obituary notice of THEODORE BREDICHIN is taken from the July number of the *Observatory:*—

With regret we have to announce the death of this distinguished Russian astronomer, which took place on May 14th last. BREDICHIN, who was a member of a noble family, was born at Nicolajoff on December 8, 1831. He was first educated at the Richelieu Lyceum in Odessa, and in 1851 became a student in the physico-mathematical faculty of the University of Moscow. In the year 1857 he was made Professor of Astronomy, and in 1873 Director of the University Observatory. He approached astronomy from many sides. He was the first in Russia to make spectroscopic observations of stars. He made observations of star-positions, of time of swing of pendulums, but his most famous works are his valuable contributions to the theory of the forms of comets and of meteor streams. In the year 1891 he succeeded OTTO STRUVE as Director of the Russian National Observatory at Poulkova, from which office he retired in 1894 on account of advancing years and the state of his health, for which the climate of Poulkova was not suitable.

Dr. ISAAC ROBERTS, F. R. S., died in July last in his seventy-fifth year. A large portion of his life was devoted to spectrum analysis, astronomy, and other kindred branches of science.

For several years he pursued stellar photography with powerful instruments specially constructed for the purpose, and succeeded in adding considerably to the knowledge of the stars, clusters, and nebulæ. In 1885 he commenced to chart by photography the stars in the northern hemisphere of the sky, but ere he had been a year engaged upon this work the French astronomers arranged that the charting of the stars should be done internationally on a uniform scale by instruments of similar construction. Dr. ROBERTS thereupon turned his attention to special researches on star-clusters and nebulæ, with long exposures of the photographic plates. These photographs have been regarded with the highest interest and admiration wherever they have been exhibited. He devised a method and a machine by which the stars that have been photographed can with accuracy be engraved directly from the negatives on copper plates for the purpose of printing; the machine is also adapted for measuring the positions and magnitudes of the stars.

The annual visitation of the Royal Observatory, Greenwich, took place on the first Saturday of June. The visitors included Sir DAVID GILL, Director of the Observatory at Cape of Good Hope, who was on a visit to England.

One rather unexpected feature in the Astronomer Royal's report is that, in spite of the unprecedented rainfall of last year, the number of observations in all departments is unusually high, the number of transits obtained with the transit circle being 13,270, the greatest number on record. In addition to the continuous observation of Sun, Moon, and planets, this instrument is devoted to the formation of a complete catalogue of all the stars from the first to the ninth magnitude that lie within 26 degrees of the North Pole. The total number of stars is about 10,000, five observations of each being required. This work is so well advanced that it has been decided to close the observations for the catalogue at the end of 1905, a year earlier than was originally intended.

The Moon was observed 106 times with the transit circle and 88 times with the altazimuth, the results showing that the Right Ascensions given in the Nautical Almanac require to be increased by 0.19 second on the average. The amount of the correction has been increasing rather rapidly in recent years, indicating that the mean motion used by the Nautical Almanac (HANSEN corrected by NEWCOMB) is slightly too small.

One important feature of last year's work has been the exhaustive analysis to which the observations of the Moon made at Greenwich during the last 150 years have been subjected by Mr. COWELL. He devised a method which enormously diminishes the labor of the analysis. One of the most interesting terms is that known as the parallactic inequality, from which the Sun's distance is deducible; the coefficient of this is found to be 124.75 seconds of arc, implying that the Sun's parallax is 8.778 seconds and his distance 93,130,000 miles. The semi-diameter of the Moon is found to be 933.75 seconds of arc, about one third of a second less than HANSEN'S value, and one second greater than the value deduced from occultations, the difference being chiefly due to irradiation at the Moon's bright limb. It would appear, therefore, that this irradiation is less than was formerly supposed. It may be noted that the Nautical Almanac will shortly supply predictions for Greenwich of occultations of stars down to the seventh magnitude, which will considerably increase the number of predicted phenomena. The great 28-inch equatorial has been devoted entirely to double-star work; 512 pairs were observed, of which 178 were less than one second apart, and 85 less than half a second. The two most difficult pairs were *Kappa Pegasi* (observed on 14 nights) and *Epsilon Hydræ* (observed on four nights), the distance in each case being one tenth of a second.

A very interesting photograph of BORRELLY'S Comet was obtained on August 1st, with an exposure of forty minutes; it shows nine distinct tails arranged in the form of a fan, the shape resembling that of SWIFT'S Comet of the preceding year.

The Sun was photographed at Greenwich on 220 days, and plates from Mauritius and India are available on 122 days, leaving only 23 days in the year without a record; some of these will be filled up, as there are some more plates to come from Mauritius. The solar activity shows a notable increase; there were only 25 days without spots, as compared with 190 in the previous year, and the mean daily spotted area increased sixfold.

It may be mentioned that a series of photographs illustrating the work of the Royal Observatory has been sent to the St. Louis Exhibition.—Extract from *The Times* of June 6, 1904.

Four hundred and fifty guests were invited by the French Astronomical Society to pass the night on the Eiffel Tower, Paris, on "Tuesday, the 21st of June, date of the Summer Solstice." The gathering was the first of the sun festivals which the Astronomical Society, inspired by its poetically tempered ex-President, M. FLAMMARION, has resolved to perpetuate. It is simply a scientific festival, with the propagation of popular interest in the wonder and beauty of the universe as one of its chief motives. All were congregated on the first landing of the tower, when the crash of a gun down below, on *terra firma,* announced that the Sun had at that moment reached the solstice. Time, twenty-eight seconds past nine.

The venerable President of the Society, M. JANSSEN, welcomed his guests at the theater on the first landing and read a short discourse, after which M. FLAMMARION delivered an eloquent address on Sun worship in the world's past, on the Sun's influence in the stellar system, and on astronomical discovery. The address was followed by a great many beautiful illustrations projected on a white screen. After that there were hymns to the Sun, invocations to the Sun and prayer to the Sun, from composers and poets, sung and repeated by artists from the Opera. A luxurious luncheon at midnight followed. Thereafter about fifty guests went to the top of the tower and waited for sunrise.—From the London *Daily News.*

The honorary degree of D. Sc. has been conferred by the University of Oxford on Sir DAVID GILL, Astronomer Royal, Cape of Good Hope.

COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to William R. Brooks, astronomer, Geneva, New York, for his discovery of an unexpected comet on April 16, 1904.

The Committee on the Comet-Medal:

W. W. Campbell,
Chas. Burckhalter.

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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ON DOUBLE STARS.*

BY R. G. AITKEN.

In the ten minutes allotted to me this morning I wish to offer some general considerations relating to double-star astronomy, to describe more particularly the work now in progress at the Lick Observatory, and to make some suggestions as to the lines of future investigation that seem to me to promise the largest returns for the time and labor invested.

Only a century has passed since Sir WILLIAM HERSCHEL announced the existence of physical systems among the stars, and but little more than three quarters of a century since STRUVE laid the sure foundations for a new department of sidereal astronomy by the publication of the "Mensuræ Micrometricæ." From an astronomer's view-point, these are short periods, and double-star astronomy is still in the primary stages of its development. Still, far more has been accomplished by the zealous efforts of its devotees than can be mentioned even briefly in the limits of this paper.

Taking account only of the double stars within 120° of the North Pole, BURNHAM, in 1896, found that nearly eleven thousand objects were included in the published catalogues. Less that half this number deserved the name of double star, judged by our present standards; for in the absence of any criterion based upon observation, the earlier observers very properly made their limits much wider than would be excusable to-day. Of the four thousand or five thousand objects that might fairly be called double stars, not more than eighteen hundred had distances of $2''$ or less. Nearly eight hundred of these close pairs were discovered by Burnham himself, and many of the others were added by Hough, See, and other recent observers. Between two hundred and three hundred pairs had given definite evidence of orbital motion, and in about fifty cases the observed motion was sufficiently great to form the basis for approximately accurate orbits.

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* Read before the Section Astrometry, International Congress of Arts and Science, St. Louis, September 21, 1904.

During the nineteenth century astronomers devoted a great deal of time to the important task of measuring these double stars, especially those contained in the catalogues of the two Struves and of Burnham, and a vast amount of observational material was accumulated. Unfortunately these measures as a whole are not readily accessible to observers, being widely scattered through the publications of observatories, the transactions of academies of science, and the scientific periodicals of Europe and America. For this reason much time has been wasted in unnecessary duplication of measures. Even more time, perhaps, has been thrown away because too many observers in their zeal have tried to make measures under unsatisfactory observing conditions and often of objects beyond the power of their telescopes. Such work only introduces confusion, and must ultimately be rejected as valueless.

So far as the double stars already discovered are concerned, I am convinced that our first need is a General Catalogue that will give not only the position of every known double star, with its description, but also enough measures of every pair to show the nature of the motion, if motion has been observed, together with complete references to all published measures. Important contributions in this line have recently been made by Innes with his "Reference Catalogue of Southern Double Stars," and by Hussey with his complete monograph on the "Otto Struve Double Stars." A much more important, because far more comprehensive, work is the General Catalogue that Burnham has been engaged upon for many years. This work is now in press, and all who are interested in double-star astronomy rejoice at the prospect of its early publication.

In the second place, the experience of the past century has made it clear that the wider double stars of the older catalogues need very little attention, and that even the moderately close pairs—those having distances of from $2''$ to $5''$—need be measured but once in ten to twenty years. Observers having access to good telescopes should therefore devote their time mainly to the measurement of the double stars with distances under 2″, especially those that have already given evidence of motion and the very close pairs of recent discovery; and they should repeat the measures of the same stars annually or biennially, according to the rapidity of the observed motion, for as many years as possible. Such a systematic series of measures of two hundred or three hundred selected stars, made by a single observer working with an adequate telescope under good conditions, will in twenty years' time add more to our knowledge of the binary systems than sporadic measures of fifty times as many pairs by a dozen observers.

But at the present time, when many leaders of astronomical thought are making extensive researches into stellar statistics, there are other questions relating to double stars, besides the theory of the motion in any particular system or systems, that are of the greatest interest.

What is the number of double stars relatively to all the stars to a given magnitude? Is this ratio the same for the fainter stars as for the brighter ones? Does it vary in different parts of the heavens, and, if so, what is the cause of the variation? These and other questions relating to double-star statistics demand an answer.

The catalogues of the HERSCHELS and the STRUVES do not afford the data needed for investigations of this nature, for the discoveries of BURNHAM, HOUGH, and others have demonstrated that the surveys of these early observers were not nearly so complete as their immediate successors had supposed. And it is also a fact that the work of none of the later double-star observers, not even that of BURNHAM, has been thorough in the sense that every star to a given magnitude in a given sky area has been examined.*

A systematic search for double stars that will include the careful examination of every star to the eighth or ninth magnitude with a good modern telescope under favorable observing conditions is therefore a prime requisite for reliable statistical researches on double stars.

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* This statement, of course, applies only to telescopic stars. BURNHAM has undoubtedly examined every naked-eye star visible in our latitude, most of them repeatedly.

There are other good reasons for making such a survey of the sky. Accurate meridian-circle observations are now extending to the stars of the ninth magnitude, and stars to this magnitude, and even fainter ones, are in daily use as reference-points in the measures of photographic plates. But moderately close double stars are obviously not suited to such uses; yet they will usually escape detection in meridian-circle observations and very often also on the photographic plates.

Such considerations as these led me, in 1899, to begin a systematic examination of all the stars given in the Bonn-Durchmusterung as of the 9.0 magnitude or brighter. This limit was adopted because it would include a number of stars (over one hundred thousand in the northern hemisphere) sufficiently large for reliable statistical studies, and would at the same time include nearly all the stars likely to be observed with accuracy on the meridian.

I had hardly begun my search when I found that Professor Hussey had independently decided to undertake a similar piece of work. We at once made plans to divide the field between us and to make our survey thoroughly systematic.

The sky from the North Pole to 22° South Declination was divided into zones of varying width, and these were so apportioned that about half of this sky area was assigned to each observer. We decided to chart to a convenient scale all the stars to be included in our survey, also marking on our charts the position and description of every double star already known. Each star was to be examined on at least one good night, and every new double star found whose components were separated by 5″ or less was to be measured on two or more nights and catalogued. We adopted this limit of distance after a careful consideration of the known binary systems as being wide enough to include all pairs at all likely to prove of interest as binaries. At the same time this limit was none too wide if we wished our lists to include all pairs likely to affect meridian observations or the measures of photographic plates.

Having formulated our general programme, we have given part of our time for the past few years to its execution, each observer working independently but in entire harmony with the other. Our survey is not quite half completed, but the results already obtained have far exceeded our expectations.

At the present time* Professor HUSSEY has found 1,035 new pairs, while my own discoveries exceed 875. These new pairs are practically all within our limit of 5″, seventy-three per cent. of them have distances of 2″ or less, and 142 are very close pairs, with distances under 0″.25. The number of pairs of this latter class in all other catalogues combined is less than 100.

I have made counts in several zones 4° wide, and from 90° to 360 long, which I have thoroughly examined, including in all more than twelve thousand stars to the 9.0 magnitude. In these zones the ratio of new double stars to the whole number of stars examined varies from 1 : 27 to 1 : 36; hence I conclude that a ratio of 3 : 100 will be a fair average for the whole region so far surveyed. This ratio refers only to the new discoveries. When we include such of the double stars previously known as fall within our limits of magnitude and distance, counts that I have made in two long zones show that the ratio of double stars under 5″ to all the stars to 9.0 magnitude is 1 : 18 or 1 : 20.

New pairs are found as readily in the well-observed northern sky as in the zones south of the equator, but neither the new pairs nor those previously known are uniformly distributed over the sky. There are large areas that contain very few known double stars in which we have added but few new pairs. In other large areas the ratio of double stars to all stars to 9.0 magnitude rises as high as 1 : 8. It is clear that such facts as these have a physical significance, and must be taken into account in framing adequate theories of cosmogony.

These ratios are only first approximations, but we are satisfied that, when our programme is fully carried out, our charts will afford ample data for the discussion of all statistical questions relating to the double stars within 112° of the North Pole. Of course, we do not suppose our search to be exhaustive, but we have very good reasons for thinking that the percentage of visual double stars that are overlooked is too small to have any sensible effect upon general conclusions.

No argument is needed to show the desirability of extending to the South Pole the search for new double stars on the systematic plan of the survey now in progress at the Lick Observatory. Indeed, when we consider how little attention the southern double stars have received in the past and how completely they are being neglected at present, it is clear that this is the most important double-star work that can now be undertaken,—especially if the programme is made to include the remeasurement of the closer pairs already known.

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* September 10, 1904.

From our experience at the Lick Observatory, it is my opinion that such a survey can be carried out by a single observer in four or five years' time, provided his telescope is as favorably located as those on Mt. Hamilton, and that a refractor of from twenty-four to twenty-seven inches aperture, all things considered, is best adapted to the work.

We find that on good nights (seeing three or more on a scale of five) we can examine from two hundred to two hundred and fifty stars per night without undue strain upon our eyes. Assuming that the number of stars to 9.0 magnitude in the southern hemisphere is not much greater than in the northern, six hundred nights would suffice to examine the stars to this magnitude south of —22° Declination, and to measure on two or three different nights each new double star discovered. At Mt. Hamilton, six hundred good nights would ordinarily mean about four years' time.

Examination of the catalogues of double stars discovered at the Lick Observatory will show that very few pairs are closer than 0″.15, and that the percentage of pairs with one component fainter than 14.5 magnitude is also very small. The visual double stars, therefore, that are beyond the reach of a good 24-inch refractor are so few that such a telescope is adequate to the work, and the greater ease with which it can be handled, as well as the small relative cost, seems to recommend it for this purpose even in preference to another 36-inch. This assumes, of course, that the mechanism of the mounting, dome, and floor of the smaller telescope is as perfect and as convenient for the observer as that of our 36-inch.

When such a survey of the entire sky has been made it will be possible to discuss double-star statistics with reasonable assurance of reaching definite and reliable conclusions. This alone will be ample compensation for the labor and time required to carry it out. The very large number of interesting binary systems it will certainly reveal to us is a strong additional incentive to the work.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1905.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

New Moon,	Jan.	5, $10^h\ 17^m$ A.M.	New Moon,	Feb.	4,	$3^h\ 6^m$ A.M.
First Quarter,	"	13, 12 11 P.M.	First Quarter,	"	12,	8 20 A.M.
Full Moon,	"	20, 11 14 P.M.	Full Moon,	"	19,	10 52 A.M.
Last Quarter,	"	27, 4 20 P.M.	Last Quarter,	"	26,	2 4 A.M.

The first of the four eclipses of the year will occur on February 19th, and will be a partial eclipse of the Moon. It will be visible generally throughout the eastern hemisphere, but not in the western. The maximum obscuration will be a little less than one half of the Moon's diameter.

Mercury will be a morning star throughout January and February. It passes inferior conjunction with the Sun December 31, 1904, reaches greatest western elongation on January 22d, and will come to superior conjunction on March 9th. It is too close to the Sun to be seen on January 1st, but rapidly increases its distance, so that it rises more than an hour before sunrise before the middle of the month. During the latter half of January the interval is never less than an hour. After February 1st the interval becomes much shorter, and the planet is too close to the Sun for naked-eye observations after the first few days of the month. The greatest elongation, on January 22d, is 24°. This is rather greater than usual, as the planet is then within a short distance of aphelion, which comes on February 9th.

Venus continues as an evening star, remaining above the horizon about three and one half hours after sunset on January 1st, and this interval increases to nearly four hours during February. It reaches its greatest east elongation, 46° 41′, on February 14th. The part of the ecliptic in the neighborhood of the planet is much nearer the pole than the place occupied by the Sun, and this makes the interval between the setting of the Sun and the setting of the planet much greater than it is usually at the period of greatest elongation. During the two months' period the planet moves about 57° eastward and 20°

northward from *Capricorn* through *Aquarius* and *Pisces* to the extreme eastern part of the latter constellation. On the morning of February 3d it is very near the vernal equinox. The actual distance of the planet from the Earth diminishes quite rapidly, and there is consequently a marked increase in brightness, but the planet will not attain its maximum brilliancy until near the end of March.

Mars rises at 1:15 A. M. on January 1st and at 11:35 P. M. on February 28th. It moves about 25° eastward and 8° southward from a point in *Virgo* a little east and north of *Spica, α Virginis,* to the eastern part of *Libra,* and at the close of February will be about 18° west and north of *Antares, α Scorpii.* Its actual distance from the Earth diminishes about fifty-five millions of miles between January 1st and February 28th, and at the latter date its distance from us is about the same as Earth's mean distance from the Sun. This causes the planet to increase about two and one half times in brightness from January 1st to February 28th. *Mars* will thus be quite a conspicuous object, although from February to the time of opposition in May the gain will be in a still greater ratio.

Next to *Venus, Jupiter* is the brightest object in the evening sky. It sets at about 1 A. M. on January 1st, and at a little before 10 P. M. on February 28th. It is therefore well placed in the southwestern sky for evening observation. It moves about 7° eastward and 3° northward in the eastern part of *Pisces,* and at the end of February it is only about 5° east and south of *Venus.* The two planets will be in conjunction early in March.

Saturn will also be an evening star during the greater part of the period; but is much lower down and apparently nearer the Sun than *Jupiter* is. It may, however, be easily seen in the evening twilight throughout January. It sets about three hours after sunset on January 1st, and only about an hour after on February 1st. It comes to conjunction with the Sun, and changes from an evening to a morning star, on February 12th, but does not reach a great enough distance from the Sun by the end of the month to be seen with the naked eye.

Uranus is a morning star very close to the Sun on January 1st, but gradually increases its apparent distance from that body, so that by the end of February it rises about three hours before sunrise. It moves about 3° eastward in *Sagittarius,* and is a short distance north of the "milk-dipper" group in that constellation.

Neptune passed opposition with the Sun toward the end of December, and is therefore above the horizon during most of the night. It is in the western part of *Gemini*, and moves about 1° westward during the two months.

I.—A PROPOSED METHOD FOR THE MEASUREMENT AND REDUCTION OF SPECTROGRAMS FOR THE DETERMINATION OF THE RADIAL VELOCITIES OF CELESTIAL OBJECTS.

II.—APPLICATION TO A STUDY OF THE VARIABLE STAR *W SAGITTARII.**

INTRODUCTION.

Beginning thirty-five years ago, when HUGGINS and VOGEL first made application of DOPPLER's principle to the determination of radial velocities of stars, the methods employed in this work have been developed until at present an efficient and practically uniform system has been adopted in the various astrophysical observatories. In 1888, when the attempt was made at Potsdam to record photographically the displacement of lines in the stellar spectra, the problem was placed on a firm basis. Subsequently, through improvement in the construction of spectrographs, a more accurate knowledge of the wave-lengths of spectral lines, and signal advances in the methods of measurement and reduction of the spectrograms, the results have attained their present degree of accuracy. The probable error of 2.2^{km} per second for an average case of velocity determination with the older methods has been reduced to a few tenths of a kilometer at the present time.

Flexure and temperature change during exposure may be said to play no part in the performance of the modern properly equipped spectrograph, and other observational sources of error are well under control. Undoubtedly, the spectrograms of to-day contain information regarding the velocities of celestial light-sources more precise than our present methods of measurement and reduction are capable of bringing out. In these methods there exist certain recognized sources of accidental and systematic error which must be eliminated if the coveted hundredth of a kilometer can ever have any significance.

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* Dissertation in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the University of California. (Abstract. Complete paper published as *L. O. Bulletin*, Number 62.)

PART I.

METHODS OF MEASUREMENT AND REDUCTION OF SPECTROGRAMS.

The plan of procedure that has been widely adopted, subject to slight variation in the case of different observers, may be briefly described. The spectrogram is measured twice, direct and reversed, on an engine supplied with a microscope of adjustable magnifying power, rigidly mounted over a plate-carriage which is moved by delicate screw and micrometer system in one coordinate only, in the direction of extension of the spectrum. A set of measures includes the list of micrometer readings which correspond to the positions of the plate-carriage when the various spectral lines, both bright and dark, occupy in turn a given position with reference to some fixed point in the focal plane of the microscope. These readings, together with the laboratory determinations of the wave-lengths of the spectral lines employed for the measurements, constitute the data necessary for the determination of the radial velocity of the source emitting the light, in terms of the accepted standards of velocity. From the micrometer readings and wave-lengths corresponding to not less than three known lines in the comparison or solar spectrum, the constants of the Hartmann-Cornu interpolation formula* are easily computed. By this formula micrometer readings are readily transformed into approximate wave-lengths, and *vice versa*. If, now, each plate is to be reduced independently, as at Yerkes Observatory,† the constants of the empirical interpolation curve are computed as above from three or more comparison lines. Corrections to this curve are determined by comparison of the adopted and interpolated wave-lengths of the comparison lines, and are plotted as functions of the micrometer readings or the λ's themselves. It then remains to compute by means of this corrected interpolation formula the wave-lengths corresponding to the micrometer settings on the lines of the spectrum to be measured. We thus obtain the actual wave-lengths of these lines as affected by the motion of their source relatively to the observer. From the known wave-lengths of these lines, occurring in the spectrum of a light-source at rest with reference to the observer, a simple application of DOPPLER'S principle will yield the desired radial velocity of the star. If, on the other hand, the dispersions of one or more solar plates* be taken as standards, by measures on the comparison lines of a stellar spectrogram, the micrometer readings on the star lines themselves are reduced to the selected dispersion, and may be compared directly with the computed readings of the same lines in the fundamental table. In point of accuracy, there seems to be no choice between these two methods, but the latter one is undoubtedly shorter. The sources of error which are shared by both, I shall briefly review.

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* *Astrophysical Journal*, Vol. VIII, page 218. *Astronomische Nachrichten*, No. [illegible].

† *Publications of the University of Chicago*, Vol. VIII, page 150. *Astrophysical Journal*, Vol. XV, No. 1.

(*a*) *Change in film.*—The actual shape of the photographic film while the plate is being exposed is never reproduced, owing to distortions ascribable to temperature change and the processes of development and drying, but the effect of these distortions on velocity determinations is minute and intangible, especially when many well-distributed comparison lines are employed.

(*b*) *The measuring-engine.*—(1) Errors in screw.—Errors due to inequalities in the pitch of the micrometer screw, whether periodic or otherwise, are usually negligible in modern engines. They may, of course, be eliminated by application of small corrections to the measures, but are essentially inoperative in most velocity work.

(2) Temperature change during measures.—The effect of temperature change on the measuring-engine during measurements may play an important part unless considerable care is exercised. Measures should not be begun until the micrometer-head has been in contact with the hand for a short time, and during the measures the room temperature should be kept nearly constant. In my own work, after completing a plate,

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***Astronomische Nachrichten*, Nr. 3702. *Astrophysical Journal*, Vol. VIII, page 124.

I have tested the temperature shift by setting back on the lines first measured, and have invariably found some discrepancy. In one solar plate in particular, which had required considerable time for measurement, this shift amounted to about .003^{mm}, or the equivalent of seven kilometers' velocity. This led me to test the character of the shift by remeasurement of some of the remaining comparison lines on the plate. The plot of differences thus obtained approximated a straight line which gradually approached the original curve. Evidently the temperature change was progressive, and was entirely taken up in the first curve. Here, again, the advantage of an even distribution of star and comparison lines is apparent. Evidently, also, the "smoothing out" of curves of residuals from interpolation formulæ should not be practiced without due caution, for temperature change during the measures may produce very appreciable distortions in such a plot.

(*c*) *Subjective errors.*—Discrepancies arising from accidental errors of setting and from personal equation are among the most important to be considered. The former can be reduced only by long practice and the employment of a greater number of lines; the latter have been largely eliminated by the reversal of the spectrogram on the engine,* but it should be noted that in the reversal of a plate the spectrum is simultaneously inverted. Thus, in general, it would hardly be said that the effect of personal equation is entirely compensating in the two measures, for the appearance of a line after inversion might be so changed as seriously to interfere with the duplication of the conditions which existed before reversal. Further, in case of a straight-slit spectrograph the curvature† of the spectral lines would seriously interfere with the elimination of personal equation in this way.

(*d*) *Errors due to the assumption of wave-lengths.*—(1) An instrumental defect.—A source of error by no means inappreciable is found in the relative displacement of comparison and absorption lines due to imperfect focal conditions which obtain outside of given narrow regions of the spectrum, corresponding to the rays which pass through the prism train at

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***L. O. Bulletin*, No. 15, and *Astrophysical Journal*, Vol. XV, page [illegible]8.

† Curved slits are used on the Mills spectograph. They give straight spectral lines, which is a decided advantage.

minimum deviation, or corresponding to the intersections of the focal curve with the plane surface of the photographic plate. The so-called wings, which seriously impair the definition of the outlying lines of the comparison spectrum, undoubtedly persist far into the region of apparently sharp focus, giving rise to errors in the measured positions of the bright lines. The corresponding displacements of the absorption lines of the stellar spectra, due to the same cause, are certainly much smaller, if at all appreciable. This difference is due to the fact that much light is concentrated in the bright lines, many of which are strongly exposed in order to bring out the fainter features of the comparison. Thus the wings, though they share a relatively small part of the light, may become quite as dense as the sharp part of the lines, for the density of the sharp part of the lines is but slightly affected by light after a certain time, while the wings continue to spread.

(2) Physical differences.—Aside from subjective errors of measurement, there is no greater source of uncertainty in the reduction of spectrograms than that which arises from the assumption of wave-lengths for the star and comparison lines from ROWLAND'S solar tables. It is doubtful if the conditions of density and internal motion in the Sun and spark are sufficiently alike to warrant this procedure. But until better determinations of spark wave-lengths are available, there seems to be no alternative. A careful discussion of the matter by FROST and ADAMS* has led to the conclusion that "In the present state of our knowledge we . . . cannot say with any certainty how much our results are affected by the use of solar wave-lengths for our Ti lines; but presumably by an amount corresponding to less than 0.02 tenth-meters, or about 1.4 kilometers, and perhaps very much less." Wave-lengths in star and Sun may differ by small amounts, due to pressure, etc., but it seems practicable to assume agreement in the case of solar-type stars. In other cases the chances seem favorable.

(3) Errors in ROWLAND'S table.—ROWLAND'S determinations of solar wave-lengths are probably relatively accurate to the nearest hundredth of an Ångström Unit. Their absolute value need be known only approximately for velocity work.

(4) Errors in practice.—In actual performance some ap-

**Publications of the University of Chicago*, Vol. VIII, page 155.

parently good lines are found to yield consistently poor results, which usually lead to their final rejection. Errors in wave-lengths or intensities in ROWLAND's table, or close lines in the star, may be responsible for the trouble. However that may be, there are undoubtedly among the lines retained many which are similarly in error, but in a smaller degree. It simply remains to eliminate such lines as soon as they can be detected, though the uncertainty of proceeding in the dark in this regard is far from satisfactory.

(*e*) *Elimination of these errors.*—For errors due to change of film and inaccuracies in the measuring-engine, including temperature change during measures, adequate remedy has been proposed, but no elimination of the remaining uncertainties incident to present methods seems possible without a radical change in the system employed. As long as the wave-lengths determined from measures with the grating or interferometer by an observer of one personal equation are employed by another observer of a different personal equation to represent his measures of corresponding lines as produced by a different spectroscope, it can hardly be expected that the results of various observers will be entirely consistent. The problem demands that the conditions which obtain in the production, measurement, and reduction of a spectrographic plate of a star should be exactly duplicated in the production, measurement, and in general the reduction, of the plate from which the fundamental data for velocity determinations are secured. The same spectrograph should produce both plates. They should be measured by the same observer with the same measuring-engine. And, finally, they should be reduced in parallel. These requirements are clearly most exacting, but as a suggestion of a means toward this end, I propose the following method, which, as far as I know, has never been applied in this way.

A PROPOSED METHOD FOR THE MEASUREMENT AND REDUCTION OF SPECTROGRAMS.

Proceeding as in case of a stellar exposure with the spectrograph in final adjustment, from which it must not be disturbed, a source of accurately known velocity, such as the sky or Sun, is photographed with the comparison in the usual manner. Then the measures upon the comparison and continuous spectra of this plate with some engine by any observer will constitute his fundamental standard table for the engine and spectrograph used. These measures of the bright and dark lines of a plate of the sky or Sun and spark will fix the relative positions of the Fraunhofer and comparison lines for a known velocity, and will constitute a velocity-standard table. For the determination of the velocity of any celestial object of the same characteristics as the standard source, it is only necessary to duplicate the exposure and measures of the standard plate and compare directly the relative positions of corresponding lines of the two sources referred to the comparison spectrum of their respective plates. In the reduction of a stellar plate for velocity determination, we first reduce the star measures to the dispersion of the standard plate by forming a simple plot with micrometer readings as abscissæ and differences in settings on comparison lines as ordinates. For the star lines the reductions to fundamental dispersion are read directly from this plot. If these reductions are applied to the readings on the stellar spectrum, the measured positions of any dark line on the Sun and star plates will differ by an amount proportional to the relative velocity toward the Earth of the star and Sun.

The assumptions in this method are fundamental in every case of velocity determination. Further assumptions treated above as incident to other methods are here eliminated by the comparison of artificial lines with artificial lines and dark lines with dark lines. The advantages of this simple system need only be mentioned. Errors in the screw of the measuring-engine are eliminated for small displacements, such as are found in stellar spectra, if the standard and star plates occupy identical positions on the plate-carriage during measures. Personal equation is well controlled without the reversal of the spectrogram, and may be closely followed by frequent measures of standard plates. It may even seem preferable not to reverse the plate, for, as I have suggested, the curvature of lines may introduce a variation of this unaccountable source of error. The magnitude of accidental errors of setting is not affected by the use of this method, but with the greater number of lines available in solar-type stars particularly, the reliability of the means from any plate is clearly increased. Uncertainties due to imperfect focal conditions are not only largely eliminated if the exposures on comparison and star are consistent in star and standard plates, but the region of spectrum available for measurement can be extended without fear of encountering difficulty. The number of lines available is further augmented for solar-type stars by the possibility of including blends, which are clearly reliable under this method. Until tests are made with high-dispersion instruments, it is difficult to predict the extent of the advantage of this increase of the measurable lines for this case; but for low-dispersion instruments in my own experience with a magnifying power of twenty-five, the number of available lines increased from twenty to one hundred and seventy; and with a power of ten, though practically no lines could be used with methods depending on wave-lengths, sixty-five lines gave good results for velocity determinations. But for the present the chief advantage of the method lies in its independence of accurate relative or absolute values of the wave-lengths or intensities of the spectral lines of the spark or continuous spectrum. For the determination of the factors necessary to convert micrometer displacements into kilometers, rough relative values of the wave-lengths of three favorable spark lines are needed, but, aside from this, there is no necessity for data of this kind. It is possible to make final definitive measures at once.

In the application of this method any degree of refinement can be introduced at the will of the observer. The number of plates employed to form a standard table can be increased until the full possibilities of the spectrograph and measuring engine are realized. By comparison of standard plates any errors due to temperature change in the instrument can be detected, and tables can be prepared for different temperatures, if desired. Standard plates can be prepared occasionally and measured, along with the regular observing list, as checks on the constancy of the results. For absolute checks of the performance of the method lunar and planetary spectrograms are of course available, but the determination of the sky or solar velocities furnish equally reliable checks, and at the same time afford data for strengthening the original standard tables. In general, three sky or Sun plates should furnish sufficient data for a fundamental table, though the conditions obtaining in any particular case might call for a greater or smaller number.

This velocity-standard method is best applicable to solar-type stars, but it may, if desired, be modified to suit the requirements of hydrogen or other stars without the introduction of errors greater than those incident to present methods. Thus a standard table for any class of stars may be prepared by introducing in the spark, in addition to the regular comparison, those elements which produce good lines in the stellar spectra. The assumption is made that the relative positions of the spark and dark lines of the elements used are not affected differently either by the dissimilar physical conditions in the spark and star or by the peculiarities of the spectrograph; but this is an assumption commonly made in all spectrographic work.

PART II.

AN APPLICATION OF THE VELOCITY-STANDARD METHOD.

(*a*) *Apparatus employed.*—Necessity for some departure from the present methods of measurement and reduction of spectrograms first arose in the attempt to improve the accuracy of relative velocity determinations from spectrum plates made with *Spectrograph I* of the Lick Observatory. The performance of this spectrograph is exceptionally good. The limit of resolving power with lantern-slide plates is about 0.50 Å.U. at Hγ, which is all that could be expected of an instrument of one fifth the dispersion of the Mills. However, with rapid emulsions, the increased size of silver grains interferes seriously with the definition. Careful tests by DR. J. STEBBINS and Dr. J. H. MOORE have shown that all effects of flexure have been successfully eliminated in the construction of this instrument. But the effect of temperature change on the positions of lines is very marked. This is largely due to the unequal expansion in the triangle formed by the steel collimator tube, the brass camera tube, and the brass tie-rods which extend from the collimator tube nearly to the plate-holder. The extent of this shift has been determined by Dr. MOORE. It is equivalent to approximately 36 kilometers in velocity per degree Centigrade change in temperature. The limitations of the instrument are thus readily appreciated. In my own work, in the absence of a temperature case, the spectrograph has been wrapped in several thicknesses of woolen blanket just before the exposure began. At the same time all the windows in the dome were closed. These precautions, together with the frequent introduction of the comparison, have made good results possible, but it has been almost invariably the case that the best velocity determinations have been made from plates for which the temperature range was a minimum. Recently a temperature case and automatic thermostat have been constructed for this instrument. These may be expected to result in very material improvement in its performance.

Further disadvantages are inherent in an instrument of low dispersion and resolving power. Linear defects in lines produce five times the error that they would occasion with the Mills spectrograph. Probably no more than fifteen or twenty single lines could be measured with any power on any one plate of a solar-type star. STEBBINS found only six coincidences of solar and stellar lines for *o Ceti* in a region of 340 Å.U., while in a region covering 120 Å.U. he found twenty such lines on Mills plates. With a power of ten, absolutely no single lines would be available for velocity determinations. In view of these facts, it would seem that few tests could be more exacting than the application of the velocity-standard method to this case. Spectrograms made with an instrument of this kind, with no greater protection against temperature change, are affected by errors which accurate measurements serve to bring out; but it was one aim of the author to determine the degree of accuracy to be expected from an instrument of low dispersion, for its field of usefulness is practically inexhaustible, as it reduces the exposure time required with the Mills spectrograph by ninety per cent.

(*b*) *Application to the study of the variable star, W Sagittarii.*—Exhaustive studies of the light curve of *W Sagittarii* were made by Herr J. H. F. SCHMIDT, who discovered the variability of this star, then known as γ' *Sagittarii*, at Athens in 1866.[*] From a series of eight hundred and ninety observations, covering ten years and extending over one hundred and ninety-five maxima and one hundred and ninety-three minima, he constructed a light curve, which is drawn in detail in Plate

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[*] *Astronomische Nachrichten*, Nr. 2071, page 103.

8[*] of this paper. In addition to the strong irregularities in the curve, he suspected a perturbation in the light period running through a cycle of eight years, affecting the time of maximum and minimum several tenths of a day. But his observations were hardly extensive enough to warrant this last conclusion. The spectrographic observations at present available do not cover a period long enough to confirm or to disprove this result. As presented in the Chandler and Harvard catalogues, the important data regarding this star, with some additions, are as follows:—

Chandler's Third Catalogue.

Max., $4^{m}.8$; Min., $5^{m}.8$; M-m, $3^{d}.00$; Period, $7^{d}.59460E$.
Epoch of Max., 1866, Sept. 4; Julian, $2{,}402.849^{d}.45$.

Harvard Catalogues.

Max., $4^{m}.3$; Min., $5^{m}.1$; Class IV; Sp., G5K.
α 1900.0, $17^{h}\ 58^{m}.6$; δ 1900.0, $-29°\ 35'$.

Additional Data.

λ 1902.0, $269°\ 44'$; β 1902.0, $-6°\ 08'$.
Photo. Max., $5^{m}.5$; Photo. Min., $6^{m}.5$.

The spectrum of *W Sagittarii* approximates very closely to the solar type. The fact that sixty-five blends ranging in intensity from twelve to forty gave good results, as exhibited in the last column of Table III,[†] establishes the close resemblance of this star to our own central body. The seventeen lines in Table IV[†] suggest some differences, the most striking of which is the strong line at λ 4335.7, which is not found in the Sun, but rises to an intensity of 12 in the star. But, on the whole, the identities are far-reaching enough to warrant an extensive system of blending.

This fact justified the use of a power of ten in the measures of the plates of *W Sagittarii.* But the selection of such a low power was not decided upon without considerable experiment with a higher one. With a power of ten, the width of the micrometer thread (about 0.50 Å.U.) interfered with settings on lines of intensity 12 to 15, while the density of the comparison lines was so great that it became difficult at times to distinguish the black vertical wire when set on them. After experimenting with powers of ten, twelve, fifteen, and twenty-five, I am inclined to think that a power in the neighborhood of fifteen would perform most satisfactorily in the case of solar-type stars.

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[*] Omitted in this abstract.

[†] Tables and details of reduction are omitted in this abstract.

From preliminary measures in August, 1903, of three spectrograms of *W Sagittarii*, a very considerable variation in the radial velocity of this star was brought to light. Subsequently a series of thirty-three spectrograms, distributed uniformly in the light period, was completed with Spectrograph I. These have been measured and reduced for the purpose of determining the character of the orbit of this interesting variable. I have not been able to recognize upon these plates any effect attributable to the light of the fainter companion now known to exist, but it should be remembered that a difference of one magnitude is nearly sufficient to obliterate the effect of the darker star.

Assuming the identity of the light and velocity periods for this star, we may lay down the plot of the velocity determinations by employing the intervals after maximum as abscissæ and the corresponding radial velocities of the star with respect to the Sun as ordinates. Ample verification of the adopted value for the period was found in the close agreement between results obtained from plates covering more than forty maxima of the curve, or an interval of 309 days. But when the attempt was made to pass an elliptic velocity curve through these observations, it was found that the plotted points oscillated above and below this curve with a period of 3.8 days, or one half that of the light variation. After repeated trials of various ellipses with different values of periastron time, longitude of periastron, eccentricity, maximum positive and negative velocity, and the velocity of the system, I selected the velocity curve which is drawn on Plate 8* with the narrower line. In selecting this conic it was assumed that the actual observed velocities followed a superimposed curve with a period of 3.8 days and with nearly equal amplitudes for crests and troughs. For the better determination of the secondary curve the residuals of all plates from the ellipse were plotted after being reduced to one complete period of 3.8 days, employing the well-established nodal point at 1.7 days after the light maximum. A sine curve was then passed through these points with an amplitude of 4.2^{km} at the crest and 5.5^{km} at the trough. This final curve was superimposed on the velocity curve and is represented by the heavy line of the upper curve of Plate 8.* The residuals from this curve for all the plates appear in Table VII* under the heading *r*. Including all these residuals, and assigning equal weights to each, the resulting probable error of a single plate is $\pm 0.90^{km}$. Excluding five inferior plates whose velocities could be given very small weight in the construction of the curve, the probable error of any one of the remaining twenty-eight plates is $\pm 0.55^{km}$. The occurrence of relatively larger residuals along the crest of the secondary curve finds ready explanation when it is noticed that, of the two crests which obtain in one complete revolution of the system, the one occurs at the light maximum where the greater activity of the star could lead to wide ranges in velocity, while the other occurs at light minimum where, with increased exposure time, the effect of temperature change in the instrument becomes a maximum.

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* Omitted in this abstract.

The elements of the orbital or primary curve of the brighter component of *W Sagittarii*, together with those of the superimposed secondary curve, as are follows:—

	ELEMENTS	Primary Curve.	Secondary Curve.
Apparent period,	P'	7.59460 days	3.80 days
Longitude of periastron,	ω	70°.0	
Eccentricity,	e	0.320	0.0
Time of periastron after light maximum,	T	6.20 days	
Projection of semi-major axis on plane of sight,	$a \sin i$	$1{,}930{,}000^{km}$	
Projection of periastron distance on plane of sight,	$q \sin i$	$1{,}310{,}000^{km}$	
Projection of apastron distance on plane of sight,	$q' \sin i$	$2{,}550{,}000^{km}$	
Ratio of masses,	$\frac{m^3 \sin^3 i}{(m+m_1)^2}$	$0.00499\odot$	
Amplitude of velocity curve at crest,	A	$+21.6^{km}$	$+4.2^{km}$
Amplitude of velocity curve at trough,	B	-17.4^{km}	-5.5^{km}
Velocity of center of mass of the system,	V	-28.6^{km}	

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* Omitted in this abstract.

Our present knowledge of the elements of *W Sagittarii* makes possible the introduction of two small corrections to the period of this star depending upon the velocity of light. The first is due to the change in the distance between the Earth and the bright component of the binary system occasioned by their orbital motions, and may be regarded as the combined effect of the equations of light of the two bodies. Its operation is not systematic, but may be taken into account in the computed times for maxima used in plotting the velocity observations by changes never exceeding 0.01 days. The maximum variation from the mean in the present problem is about 0.002 days, which is equivalent to a displacement of 0.007^{cm} in the abscissæ of my original velocity diagram. It is therefore evident that this correction is negligible. The second correction to the period of this variable is based upon the continued approach of the system toward the Sun at the rate of 28.6^{km} per second. As this correction is constant, the use of the apparent period for the velocity diagram does not affect the determination of the elements which characterize the form and position of the orbit. But the epochs of the curve, referred to the time of maximum, and all dimensions of the orbit are direct functions of the true period. The correction to the apparent period amounts to + 62 seconds, or + 0.00072 days. Accordingly, the true value of the light and velocity periods of *W Sagittarii* is—

$$P = 7.59532 \text{ days.}$$

As the remaining elements of the velocity curve are published to three places only, this change in the fifth significant figure of P does not appreciably affect their values.

The angle i, which measures the inclination of the orbital plane to a plane tangent to the celestial sphere at the center of mass of the system, cannot be determined without micrometrical measures of the two components. The absolute scale of the ellipse is therefore indeterminate.

For purposes of comparison among spectroscopic studies of *Cepheid* variables, there exist in addition to the present investigation the excellent results of WRIGHT and BELOPOLSKY in connection with their researches regarding the orbits of δ *Cephei** and of η *Aquilæ*.† A strong resemblance between the elements of these stars is at once evident. All show a pronounced eccentricity. Also, the time of closest approach of the bodies of the system occurs about a day before maximum brightness. The most marked analogies exist between WRIGHT's elements of *η Aquilæ* and those of *W Sagittarii;* indeed, with the exception of a small difference in eccentricity, the uncertainty of inclination, and a difference of 0.5 days in the period, the two orbits are essentially identical even in regard to the positions of principal maximum and minimum. It is interesting to notice that Mr. WRIGHT has obtained no evidence of a secondary curve for *η Aquilæ,* but such a curve would not have been recognized if its amplitude did not exceed 2^{km}, and in some positions no great distortion of the ellipse would occur with an amplitude of five kilometers for the superimposed curve. Referring to Mr. WRIGHT's article, it should be noticed that the velocity curve reproduced there is the empirical curve which was drawn for the purpose of determining the elements. His actual ellipse passes slightly below observation 11, not above it. It will also be noticed that his observations tend above the published curve from 1 day to 2.8 days after maximum and fall below from 2.8 to 4.5 days. It therefore seems probable that some curve oscillating about an ellipse would represent the observations better.

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* *Astrophysical Journal*, Vol. I, page [illegible]

† *Astrophysical Journal*, Vol. VI, page [illegible]; Ibid., Vol. IX, page [illegible]

Mr. WRIGHT's observations extend over four months, and my own over a period of less than a year. It is therefore probable that any influence connected with the long-period irregularities in the light recurrence of these stars would escape detection. Further study of these stars should reveal such phenomena.

The observed uniform correspondence between the light variations and the orbital conditions of these three stars suggests the mutual dependence of the two phenomena. Whatever may be the cause or causes of variation in the *Geminids,* they may not operate in the same manner in the *Cepheids.* It therefore seems advisable to treat each group separately in any attempt to construct a theory for the explanation of their light changes. I shall therefore advance some data regarding the most probable conditions that obtain in the system of *W Sagittarii.*

DARWIN'S expression for tidal potential is—

$$V = \frac{3}{2}\frac{m}{r^3}\rho^2 (\cos^2 z - 1/3),$$

where r is the distance between the masses, ρ is the radius of the disturbed body, and z the angle between r and ρ; m is the mass of the disturbing body. Confining our attention to the line joining the two bodies, we place $z = 0°$ and differentiate with reference to the direction of displacement and arrive at the expression, $F = 2m\rho/r^3$, where F is the tidal force. As the ratio of apastron to periastron distance in this system is 2 to 1, it is evident that the tidal force varies in the ratio of 1 to 8 for these two positions. Using the rough conclusions as to the most probable data for the system arrived at above, we find that the intensity of the tidal force acting on the brighter body is, roughly, 50,000 times that of the Moon acting on the Earth. Further, by the introduction of another term usually negligible in tidal computations, we find the ratio of the intensities of the tidal forces on the side toward the disturbing body to the corresponding forces on the opposite side of the brighter star is 15 to 10 at periastron and 13 to 10 at apastron.

While the increase of light may be due to enormous tidal disruptions in the molten matter of the star's surface, accompanied perhaps with a liberation of heat from below, it should be noted that the displacements of the absorption lines in the spectrum are caused by the motions of the star's atmosphere with and relative to the regions emitting the light. In the atmospheric regions above the high tidal area there would undoubtedly be an uprush of gases due to atmospheric tides, convection currents, increased light pressure, and explosive outburst. Again, in the belt of low tide ninety degrees from the two high tides, there would probably be a corresponding recession of the atmosphere toward the star's surface. This would clearly give rise, in the actual velocity curve, to an oscillation with respect to a true ellipse. These oscillations would fall below the mean at conjunction and above the mean at elongation, for at conjunction the high tidal areas are presented to the observer, and at elongation the low tidal areas. Consulting the diagrams, this is found to be the case. We can therefore depart from the rotation theory to account for the secondary curve, and indeed this seems justifiable, for it is possible with the operation of such immense tides through long periods of time that the rotation periods of the stars involved should be brought to identity with the revolution period, as in case of our own satellite. Further, on the basis of the tidal theory, there would not seem to be sufficient variation in brightness due to difference in intensity of the tidal force between the two hemispheres (the ratio is about 7/5) to produce by rotation the oscillation observed, unless we assume much greater masses for the system. The occurrence of the light maximum when the tidal forces have fallen one third in intensity presents an anomaly, but it is possible that the effect of these forces lags to this extent.

Returning again to the rotation interpretation, it is easy to construct a plausible explanation for the light and velocity curves of *W Sagittarii* on the assumption that the system is pervaded by a resisting medium which enhances the brightness of that side of the star which faces the direction of motion. Or, again, a third body might be present in the system and give rise to the perturbations observed by SCHMIDT in the period. Until more data are available, to follow out such theories would be premature.

Considering all evidence, it seems reasonably certain that the star's variations in brightness, and particularly the principal variations, are attributable to the action of external forces.

It is a pleasure to acknowledge my indebtedness to Director CAMPBELL, who placed the necessary apparatus at my disposal and gave continual counsel and encouragement during the prosecution of the work, and to Dr. H. D. CURTIS and Dr. J. H. MOORE for valuable advice and assistance.

July, 1904. RALPH H. CURTISS.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

CASTOR A QUADRUPLE STAR.

The second-magnitude star *Castor,* in the constellation *Gemini,* is known to all students of astronomy as a very interesting double star. In fact, Sir WILLIAM HERSCHEL, the pioneer of double-star astronomy, called it the largest and finest of all the double stars visible to observers in the northern hemisphere. It is also very interesting historically; for the motions in its system first convinced HERSCHEL that there are systems in which two or more bright stars are revolving around each other in orbits of short period.

The two component stars of *Castor* are a little brighter than the third and fourth magnitudes, respectively. They are about five and one half seconds of arc apart, and revolve around their common center of mass in approximately three hundred and fifty years, according to the latest calculations. An uncertainty of one hundred years at least exists in this estimate, for the reason that accurate observations of the relative positions of the two stars have been made for less than one hundred years.

An interesting discovery concerning the fainter of the two components of *Castor* was made, nine years ago, by Astronomer BÉLOPOLSKY, of the Russian National Observatory at Pulkowa. While engaged in measuring the speed with which the two components are traveling to or from the observer, he discovered that the speed of the fainter component is variable. On one night the star would move toward the solar system; on another night it would move rapidly in the opposite direction, and later it would prove to be rapidly approaching. A long series of observations has established that the speeds of this star pass through a complete cycle of change in a little less than three days. The explanation of the variable speed is, that this star is attended by an invisible and very close companion, massive enough to swing the bright star around in an elliptic orbit once every three days.

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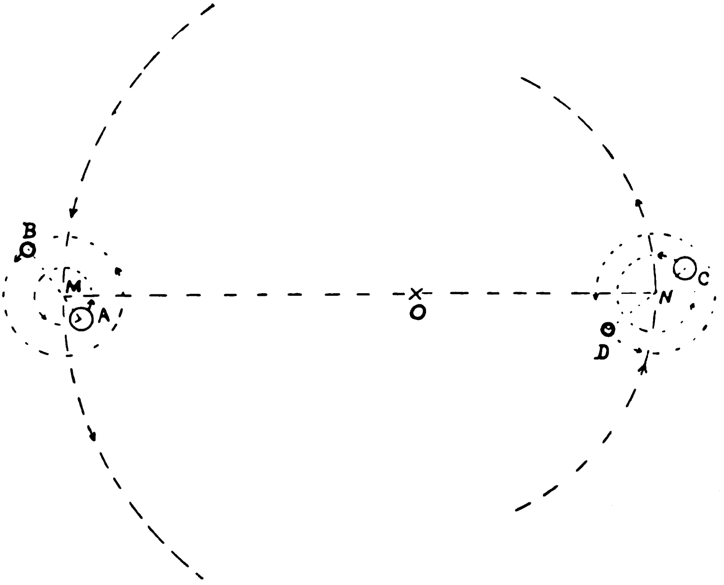
* Lick Astronomical Department of the University of California.

The purpose of this article is to call attention to the discovery, just made at the Lick Observatory, that the other and brighter component of *Castor* is likewise attended by an invisible component, which causes the speed of the bright star to vary. At one time it is approaching us, and a few days later it is receding. The number of days required for the bright star and the invisible component to complete a revolution about their center of mass will not be known until a considerable number of observations have been secured, within the com



The System of *Castor*.

weeks. The discovery was made by Dr. CURTIS
Mills spectrograph attached to the 36-inch refrac

In the accompanying illustration a rude att
to illustrate the relationship of the stars in thi
C are the visible components of *Castor*.

the invisible component B, discovered spectroscopically by BÉLOPOLSKY, and the two revolve around their center of mass, M, in slightly less than three days. The brighter star, C, is attended by the invisible companion, D, just discovered by Dr. CURTIS, and the two revolve around their center of mass, N, in a period as yet unknown. The two systems AB and CD revolve about their center of mass, O, in a period of approximately three hundred and fifty years. It should be said that the distances AB and CD are drawn relatively too large, and the distance MN vastly too small.

Great progress has been made in the study of double stars since the days of HERSCHEL. The known systems are numbered by the thousands, and the current work of Astronomers HUSSEY and AITKEN has established that, of stars brighter than the ninth magnitude, at least an average of one in eighteen is composed of two suns, visible in our great telescope. Although the components in each pair appear to be very close together, yet their distances from each other are so great, in all cases, that many years are required to complete one revolution. The shortest period, that of δ *Equulei*, is nearly six years. There are only thirty or forty whose periods are known to be less than one hundred years, and in the great majority of cases the periods will be expressed in hundreds and thousands of years.

The invention of the spectrograph, and its application to the measurement of stellar velocities of approach and recession, have enabled us to make a most interesting extension of our knowledge of binary systems. We are enabled to discover companion stars so close together that the most powerful telescope cannot separate them. In fact, their discovery becomes easier as the distance between the components becomes less. In the past few years more than a hundred such systems, known as spectroscopic binaries, have been discovered at a few of the leading observatories. It has in fact been established that, of the stars visible to the naked eye, at least one star in six is attended by an invisible companion, each so close to the bright component that the companion cannot be directly observed. In these systems the periods of revolution vary from one or two days, as a minimum, to a few years, as a maximum. For example, in the case of the North Pole star, the bright star and an invisible companion revolve around each other in a period of four days, and this binary system and a second invisible component revolve around each other in from ten to twenty years. Easily the most interesting of all stellar systems thus far studied is that of *Castor,* as described above. It does not follow that the two invisible members of this quadruple system are really dark bodies. If they are two or three magnitudes fainter than the bright components, they would be invisible; for their light would be lost in that of the principal stars.

It should be said that the great value of the discovery of this interesting system lies not so much in the discovery itself as in the opportunity thereby afforded to study it thoroughly.

November 25, 1904. W. W. CAMPBELL.

A DIVISION OF THE STARS IN SOME OF THE GLOBULAR CLUSTERS, ACCORDING TO MAGNITUDE.

The programme of observations for the Crossley reflector undertaken by the late Professor KEELER contained eight well-known globular star-clusters.

The general appearance of these clusters is very similar; they are of nearly the same angular dimensions, and the magnitudes of the component stars are remarkably alike.

In each of these clusters practically all of the stars can be separated into two classes of magnitudes. Perhaps a third of the whole number lie between eleventh and thirteenth magnitude, while almost all of the remainder are very faint, being about sixteenth magnitude. The appearance is that of two layers, one of bright stars superposed upon another of very faint stars.

But few stars of magnitudes fourteen to fifteen and one half are to be found in these clusters.

Photographs of the ω *Centauri* cluster obtained at the Harvard College Observatory station at Arequipa exhibit the same division of the stars in that cluster into two groups, as does the Crossley series. The limits of the area of the faint stars are fully as sharply defined as those of the brighter ones, and the centers of the two groups coincide. We are therefore led to the conclusion that in each case the observed division is in the same group of stars in space. That it is characteristic of all clusters of this type is not certain, but the lack of any exceptions in the clusters observed strongly suggests such an hypothesis.

Two hypotheses to account for the peculiar distribution in magnitude suggest themselves: 1st. That it is due to a difference in the size of the stars; 2d. That it is due to a difference in constitution or physical condition.

The almost complete lack of physical data at present prevents any useful discussion of these hypotheses. Although the first appears to be the most probable, yet it is conceivable that this peculiar distribution might result from a difference in constitution of the stars themselves.

In this connection attention may be called to the relation which has been supposed to exist between the nebulæ and the star-clusters. The belief has been gaining way since photography has shown the real structure of so many of these objects that they are but different stages in the process of evolution; that a star-cluster has been formed by the condensation of the matter in a nebula.

A study of the nebulæ which have been observed with the Crossley reflector shows that a large proportion are spiral, and that practically all the spirals are lenticular or disk-shaped. Many of them are relatively very thin. Now, if the globular clusters are really spherical, as seems probable, it is difficult to see how they could have originated from a disk-shaped nebula (spiral?).

As there are other forms, also, of nebulæ and star-clusters, it is not necessary to assume that the order of evolution mentioned above is the only one. But the natural tendency has been to connect such changes as these with the spirals which, by their appearance, seem to indicate greater systematic internal activity than others.

C. D. PERRINE.

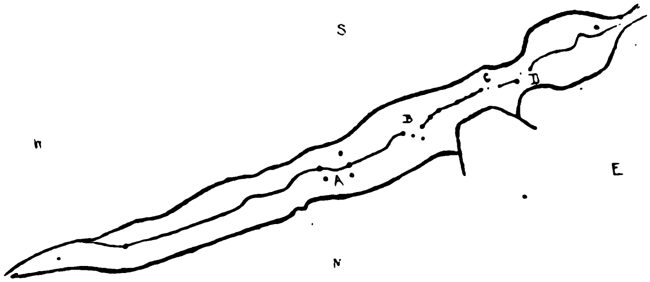
July 17, 1904.

OBSERVATIONS OF A RILL EXTENDING THROUGH THE LUNAR VALLEY OF THE ALPS.

On the night of April 23, 1904, while showing the regular Saturday-night visitors the Moon through the 36-inch refractor, I noticed a rill at several points in the Alpine Valley. The seeing was too poor to make satisfactory observations, but at times the rill could be glimpsed for nearly the whole length of the valley. It was observed on April 23d, May 6th, 22d, 23d, June 4th, July 2d, and August 30th, under both evening and morning illumination.

The rill extends the entire length of the valley, through the middle, and is continuous except at three points. It was suspected to cross one of these short gaps, and it is possible that, by observing diligently under good conditions, the rill could be traced across them all. It is visible only when the Moon is from eight to nine days, and twenty to twenty-one days, old. Owing to extreme narrowness,—the width is from three hundred to six hundred feet,—the rill can be seen only with a large telescope, and requires excellent atmospheric conditions.

The accompanying drawing is compiled from all the sketches. No attempt has been made to include details except such as are connected with the rill, or craterlets very near to it. Attention may be called to the great number of craterlets strung along the rill in some regions and to the fact that at all the gaps the rill terminates in craterlets.



Rill in the Valley of the Alps.

I have examined a number of the negatives of this region of the Moon, taken with the 36-inch refractor, especially those taken with an enlarging lens, but fail to find any trace of the rill upon them.

C. D. PERRINE.

October 16, 1904.

THE NUMBER OF THE NEBULÆ.

Professor KEELER, soon after beginning his program of work with the Crossley reflector, showed that the number of the nebulæ is very much greater than had been supposed. He conservatively placed the number within reach of that telescope at one hundred and twenty thousand. The recent completion of this program enables us to revise his estimate.

In fifty-seven regions seven hundred and forty-five *new nebulæ* have been discovered. There were one hundred and forty-two known nebulæ in these regions, making the total number of nebulæ observed eight hundred and eighty-seven, an average of eight and one half per region. As it would take sixty-two thousand such photographs to cover the entire sky, the results indicate five hundred thousand as the corresponding number of nebulæ within reach of the Crossley reflector. This assumes that the small portion observed represents fairly the entire sky.

Longer exposures, more sensitive plates, and more perfect photographs will undoubtedly reveal some nebulæ which do not now appear and others which are confused with the faint stars. It seems probable, therefore, that the number of the nebulæ will ultimately be found to exceed a million.

June 18, 1904. C. D. Perrine.

A New Mounting for the Crossley Three-Foot Mirror.

The new mounting for this excellent mirror, which has been in the process of installation during the past year, was so far completed as to permit of its use in obtaining photographs of the ninth satellite of *Saturn*. The focus was determined (photographically) on November 5th, and on the following night observations of *Saturn* were begun. A few minor improvements have since been made, and some final adjustments are still necessary.

So far as it has been used, the telescope is very stable. No change of focus or collimation can be detected when the telescope is moved over a considerable range of zenith-distance.

A description of the telescope will be published soon.

November 28, 1904. C. D. Perrine.

The Total Eclipse of September 9, 1904.

A total eclipse of the Sun occurred on September 9, 1904. The shadow path crossed the central Pacific Ocean from west to east without touching known land, except that it reached the coast of northern Chile six or eight minutes before sunset. Astronomer WILLIAM H. WRIGHT, in charge of the D. O. Mills Expedition from the Lick Observatory to Santiago, Chile, states that Dr. OBRECHT, Director of the National Observatory of Chile, established an observing-station at Taltal, but that the sky was cloudy at the time of totality. At Santiago, the sun set, partially eclipsed, on a fine horizon. W. W. C.

EXPERIMENTAL DETERMINATION OF THE SOLAR PARALLAX FROM NEGATIVES OF *EROS* MADE WITH THE CROSSLEY REFLECTOR.

In order to determine the value of the series of photographs of *Eros* which was made with the Crossley reflector, and to test a simple diurnal method of combining the results, six negatives were selected from the exposure of December 5, 1900. Three of the negatives were taken in the evening and three in the morning.

The measures and reductions were kept wholly in rectangular coordinates.

The result follows:

$$\pi_{\odot} = 8''.788 \pm 0''.008$$

The probable error of one equation of condition is $\pm$ 0″.022. The probable errors of the position of one star upon a plate, being the mean of four exposures, are

$$\text{in } X = \pm 0''.08$$
$$\text{in } Y = \pm 0\ .09$$

C. D. PERRINE.

OBSERVATIONS OF *PHŒBE*, THE NINTH SATELLITE OF *SATURN*.

Photographs showing PICKERING's new satellite of *Saturn* were secured with the Crossley reflector on November 6th, 7th, 8th, 9th, and 10th, with exposures of one and three fourths to two hours. The satellite is of about the seventeenth photographic magnitude. A comparison of these observations with PICKERING's orbit gives no residual in position-angle, but in distance there is a difference of 1′.4, the satellite being nearer to the planet than indicated by the ephemeris. At the time of these observations, the satellite was 22′ southwest of *Saturn*.

November 28, 1904. C. D. PERRINE.

THE RADIAL VELOCITIES OF *S SAGITTÆ* AND *Y SAGITTARII.*

Measures of seven plates of *S Sagittæ*, employing the lo power sky standard-table described on page 249 have resulte in the detection of a wide range in the radial velocity of thi star. As a whole, these plates are much below the average excellence, but are sufficiently reliable to establish the binary character of this variable. The accompanying table contains th number of the plate, the Greenwich date, the interval sinc maximum, the velocity referred to the Sun, the number o lines used for each plate, and the temperature change durin the exposure. If the velocities are plotted in the usual wa assuming the identity of the light and velocity periods, the are seen to follow a curve in every way similar to those o *η Aquilæ* and *W Sagittarii*, and the elements will approximat closely to those determined for *W Sagittarii*. There is als some evidence pointing to a composite character for the curv

No. Plate.	Date.		Interval since Maximum.	*V*.	Number of Lines.	Temperature Range.	Remarks.
28F	1903 Aug.	9.9	$1^d.4$	$—20.3^{km}$	20	0°.4C	Underexposed.
33E		14.9	6 .4	—32.2	44	0 .1	
35D		16.9	0 .0	—30.2	45		
42B		26.9	1 .6	—20.2	20	0 .3	Underexposed.
54B	Sept.	6.9	4 .2	+ 3.9	41	0 .1	Comparison poo
72B		13.8	2 .8	—17.3	37	0 .0	on one side.
3350C	1904 July	20.9	3 .7	— 3.9	9	0 .0	Underexposed.

As the result of relative measures of four lines on tw plates, Dr. STEBBINS found a range of 9^{km} in the radial velocity of *Y Sagittarii*. My own measures of nine plates of this sta indicate that it is approaching our system, but not at a constant rate. The range of velocity so far observed amounts t 17^{km}. The form of the curve seems quite different from tha of other *Cepheid* variables, but the character and number o the plates available are not such as to warrant any definite conclusions on that point.

RALPH H. CURTISS.

July, 1904.

NEW COMPANIONS TO KNOWN DOUBLE STARS.

In the course of my search for new double stars I hav recently found that one component in each of the well-know pairs, *Winnecke* 3 and Σ 2775, is itself a close double star.

The former is the more interesting discovery, as the pair is separated by less than 2″, and has shown some change in angle, making it probable that we have here a ternary system. The pair Σ 2775 is so wide as to possess no interest, but the new pair, forming the principal component of the Struve pair, is certain to prove a binary. The positions of the stars for 1900, the mean of my measures, and an early measure of the old pairs for comparison, are as follows:—

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* From *Lick Observatory Bulletin*, No. [illegible]

Winnecke 3. R. A. $5^h\ 18^m\ 46^s$; Decl. —0° 58′.

1904.85	141°.5	0″.25	8.0—8.1	3^n	36-inch	B and C.
4.85	160 .5	1 .87	7.7—7.8	3	36-inch	A and BC.
1863.9	170 .7	1 .61	Measures by OTTO STRUVE.			

Σ 2775. R. A. $21^h\ 09^m\ 32^s$; Decl. —1° 15′.

1904.71	43°.8	0″.14	7.6— 7.8	3^n	36-inch	A and B.
4.67	177 .7	21 .27	7.2—10.5	1	36-inch	AB and C.
1825.88	178 .8	21 .15	Measures by STRUVE.			

November 22, 1904.

R. G. AITKEN.

DISTINGUISHED VISITORS TO THE LICK OBSERVATORY.

Of the many distinguished men of science who visited the Lick Observatory in recent months, the following may be mentioned:—

Professor SVANTE ARRHENIUS, of Stockholm. During his stay special interest was taken in the subject of the nature of the solar corona, and Professor ARRHENIUS embodied his views in a valuable paper. Inasmuch as he was at the time a member of the Faculty of the University of California, his paper was issued as a Bulletin of the Lick Observatory.

Professor HECKER, of the Royal Geodetic Institute, Potsdam. Magnetic observations were made at Mount Hamilton in connection with Professor HECKER's around-the-world survey.

Professor EMILE PICARD, Member of The Institute, Paris.

Professor HENRI POINCARÉ, Member of The Institute, Paris.

Professor H. H. TURNER, President of the Royal Astronomical Society, and Director of the Oxford Observatory.

Professors ARRHENIUS, PICARD, POINCARÉ, and TURNER were leading speakers at the St. Louis Scientific Congress.

W. W. C.

DUPLICITY OF 31 β *LEONIS MINORIS.*

The Durchmusterung magnitude of this star is 4.0. I hav recently found it to be a close double. The companion is fro two to three magnitudes fainter than the principal star, an situated in the direction 232° at a distance of not quite half second.

From the character of this pair, I should at once say that is probably a binary; that the two stars are physically co nected is almost certain from the amount and direction of t proper motion. β *Leonis Minoris* is given in the fund mental star catalogues with a well-determined proper motio amounting to 0″.164 per year in the direction 225°. Were t two components not moving together, this would have been very easy pair a few years ago, and its duplicity could hardl have escaped detection even by the meridian observers.

The position of the star for the epoch 1900 is

R.A. $10^h\ 22^m\ 6^s$; Decl. $+37°\ 13'.2$.

W. J. HUSSEY.

ON THE SPECTRA OF *R SCUTI* AND *W CYGNI.**

Observations of the spectra of *R Scuti* and *W Cygni* a particularly valuable, as these stars occupy a unique positi between the short-period variables on the one hand and t *o Ceti* variables on the other. Visual observations of *R Scu* by ESPIN have led him to suspect the presence of bright lin in its spectrum, but he seems to have been unable to identi them. As far as I know, *W Cygni* had not been observed wi the spectroscope.

Exposures upon both these stars with Spectrograph I we begun in the middle of July, 1903. They were continued until November 11, 1903, in case of *R Scuti*, and December 2 1903, in case of *W Cygni*. *R Scuti* was examined visually wi the spectrograph until December 7th. In the mean time, *Scuti* rose to maxima toward the end of July and the beginning of October, while maxima of *W Cygni* occurred early August and in the middle of December. During this peri about twenty-five spectrograms of *R Scuti* and twenty of *Cygni* were secured with Spectrograph I.

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* From *Lick Observatory Bulletin*, No. 62.

On plate 13E of *R Scuti*, Hβ, Hγ, and Hδ shone out strongly as bright lines, but they faded quickly until at minimum the spectrum of the star departed but little from the solar type, with dark hydrogen lines of customary intensity. At the two subsequent maxima the bright hydrogen lines were not seen, but the intensity of the absorption line at Hγ seemed to have decreased very much as the star approached its maximum of October. Judging from rough measures of a few plates, the radial velocity of this star appears to be constant and about $+ 42^{\mathrm{km}}$ in actual value.

W Cygni shows a banded spectrum of a type characteristic of long-period variables. At the maximum of August, 1903, the hydrogen lines mentioned above appeared as strong bright lines which faded gradually to the star's minimum, while the absorption line at *g* broadened greatly during the same period. Other suspected bright lines in the spectrum of this star remain to be identified.

A detailed study of these plates will be made at the earliest opportunity.

Ralph H. Curtiss.

July, 1904.

GENERAL NOTES.

Our readers will remember that in 1899 Professor W. H PICKERING announced the discovery, from plates taken in Per in August, 1898, of a ninth satellite of *Saturn*. Months, eve years, elapsed without any verification, either visual or photographic, of this discovery. Professor PICKERING has obtaine many photographs of this tiny member of the solar system and recently the interesting announcement was made that Professor BARNARD had seen and measured this object with th great telescope of the Yerkes Observatory.* The satellite ha been called *Phœbe,* and Professor BARNARD estimates its visua magnitude to be 16.7.

Harvard College Observatory Annals (Vol. LIII, part 3) recently issued, gives in detail Professor PICKERING's wor upon this object. The most interesting announcement concerning this new member of the solar system is, that its motio about *Saturn* is retrograde, while that of all the other satellite of *Saturn* is direct. The period of revolution about *Satur* is 546.5 days, and the eccentricity of the orbit, 0.22, is greate than that of any other satellite or large planet, and is exceede by only a few of the asteroids. As seen from *Saturn* the magnitude of *Phœbe*, when full, would vary between 5.2 and 6.2 Its diameter is estimated to be between one hundred and tw hundred miles.

Dr. FRANK McCLEAN, of Tunbridge Wells and London and a member of the Astronomical Society of the Pacific, die on the 8th of November last, in his sixty-seventh year. H was trained as a civil engineer, but relinquished professiona work in 1870. A few years after his retirement he establishe an astronomical observatory at Tunbridge Wells, and fro that time forward was much engaged on solar and stellar spectroscopic work. In 1890 he founded the Isaac Newton Studentships at Cambridge, where he had graduated as a Wrangle in 1859. In 1894 he presented to the Royal Observatory at the

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* See also the note on page [illegible] for observations by Professor PERRINE with th Crossley reflector.

Cape of Good Hope the Victoria photographic telescope, of 24-inch aperture. He afterwards discovered the presence of oxygen in the helium class of stars, and in 1899 was awarded the gold medal of the Royal Astronomical Society for his photographic survey of star spectra in both hemispheres and for other contributions to the advancement of astronomy. He was a Fellow of the Royal Society and also of the Royal Astronomical Society.—*London Standard.*

In *Harvard College Observatory Circular* (No. 88) Professor E. C. PICKERING announces the discovery, photographically, of a new variable of the *Algol* type. The star is in the constellation of *Sagittarius,* and is designated —15°. 4905. Three hundred plates were available for the study of this star, and on twenty-eight of them it was found to be fainter than the normal brightness, 9.55.

"The observations indicate that the times of minimum may be represented by the formula J. D. 2,410,002.677 + 3.45348 E. An interesting feature in the variation is found in the fact that a secondary minimum occurs midway between the primary minima represented by the formula."

The first ordinary meeting of the Edinburgh Royal Society for the present session was held on the evening of November 7th in the Royal Institution, Mound—Lord M'LAREN, Vice-President, in the chair. Dr. J. HALM, Assistant Astronomer, Royal Observatory, Edinburgh, read a paper on Professor SEELIGER'S "Theory of Temporary Stars." The lecturer attempted an explanation of the peculiar features of the *Nova* spectrum on the basis of SEELIGER'S well-known hypothesis, according to which the outburst of a new star was due to the collision between a dark cosmic body and a cloud of tenuous nebular or meteoric matter. He showed that the peculiar displacements noticed in the spectral lines were due to motions of gaseous matter engendered by the impacts. Their ideas of these motions had hitherto been inadequate, because the influence of gravitation had been neglected. So far only the relative motion of the star against the nebula had been considered, the consequence being that assumptions became necessary which rendered the theory unacceptable. But the gravitatio attraction of the star on the cloud particles produced motions o such a character and magnitude that most of the hitherto enigmatic spectra features were brought within the range o physical explanation. From this point of view, two importan conclusions might be reached. First, they were practically unlimited in their assumptions as to the amount of heat develope by the impact. It could be shown that a bombardment of th star by matter whose density was only the one two-thousand millionth part of that of air at ordinary pressure and temperature was sufficient to produce an amount of heat equal to tha radiated by the Sun into space. This stupendous heating of th star's surface was necessarily followed by the formation of a atmosphere of incandescent gases and vapors which expande at an enormous rate. The velocity of these expanding gase might indeed be supposed to exceed even those noticed in sola eruptions. The author showed that the most important feature of the typical *Nova* spectrum could be sufficiently accounte for by considering the motions of this expanding atmospher Especially noteworthy was the explanation from this point o view of the uniformity of type in the spectra of all the *Nov* hitherto observed. The second conclusion was drawn fror the consideration that the impact of the meteoric cloud mus always be more or less unsymmetrical or one-sided. This wa shown by the author to lead to the formation of a gyratin ring of incandescent nebular matter revolving round the sta nucleus, with a speed probably not much less than four hundre kilometers per second. While the expanding atmosphere determined the appearance of the spectrum during the earli stages, the orbital motion of matter in the ring became prominently apparent in the last period of the star's developmen The two conclusions, which seemed to be unavoidable, if one the soundness of SEELIGER'S fundamental assumption was admitted, were sufficient to explain the facts so far observed an to form a mental picture of the physical development of thes celestial catastrophes in accordance with what had actuall been noticed. The author laid particular stress on the fact tha the observations pointed conclusively to DOPPLER'S principl as the basis from which the features of the *Nova* spectrun must be explained, and he dwelt upon the difficulties whicl were experienced if the problem was approached from othe points of view. He also suggested that his second conclusion —viz., the formation of a permanent rotating ring round the star in consequence of one-sided collision—might perhaps account for the origin of the rotation of our own solar system. He pointed out the serious objections to LAPLACE'S conception of the original solar nebula, in which this rotation had to be supposed as a pre-existing quality of the solar matter, and thought that this new point of view, which assumed as the starting-point of solar evolution the encounter between the Sun and a cosmic cloud of considerable density, besides affording an explanation of the origin of rotation, would be less open to the mathematical criticism to which LAPLACE'S theory had in recent times been so severely submitted. All conclusions seemed to point in the one direction, that the solar nebula, during its primordial stage, must have been heterogeneous to a degree in no way compatible with the Laplacian conceptions, but quite imaginable if a collision of the kind here indicated was accepted. Communications were also read by Dr. MUIR on the "Sum of the Signed Primary Minors of a Determinant," on "Continuants Resolvable into Linear Factors," and on the "Three Line Determinants of a Six-by-Three Array."—*Extract from the Scotsman.*

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS HELD IN THE ROOMS OF THE SOCIETY, NOVEMBER 26, 1904, AT 7:30 P.M.

President EDWARDS presided. A quorum was present. The minutes of the last meeting were approved.

The following resolutions were adopted to fill the vacancies cause by the death of Mr. WM. M. PIERSON:

Resolved, That Dr. HARRY EAST MILLER be appointed a member of the Board Directors, A. S. P.

Resolved, That Mr. WM. H. CROCKER be appointed a member of the Donohoe Come Medal Committee.

The question of filling the vacancy on the Finance Committee wa laid upon the table.

It was, upon motion,—

Resolved, That no award of the Bruce Medal be made for the year 1905.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE LECTURE HALL OF THE CALIFORNIA ACADEMY OF SCIENCES, NOVEMBER 26, 1904, AT 8 P.M.

The meeting was called to order by President EDWARDS. The minutes of the last meeting were approved.

The chairman introduced the lecturers of the evening: Dr. S. D. TOWNLEY, who read a paper on "The Motion of the Earth's Axis" and Dr. HEBER D. CURTIS, whose paper was entitled "Spectroscopic Binaries." Both lectures were illustrated by a number of lantern-slides

WILLIAM MONTGOMERY PIERSON died at his home in San Francisco on the fourth day of September, 1904. He was born in Cincinnati, Ohio on February 3, 1842, and came to California in the year 1852.

Mr. PIERSON studied law while very young, and successfully passed the legal examinations before he arrived at the age of twenty-one years. He was permitted to enter upon his chosen career before reaching his majority, by special act of the Legislature, approved March 20, 1862. During his long career as an attorney at law he became one of the most eminent members of the legal profession on this Coast.

Notwithstanding his active business life, he found time to devote himself to the sciences, of which Astronomy claimed his special interest. He took a prominent part in the organization of the Astronomical Society of the Pacific at its first meeting, on February 7, 1889; he was its first Vice-President, its second President, and, from its foundation until his untimely death, a member of the Board of Directors, and of the Finance and Comet-Medal Committees.

In addition to his continuous efforts to promote the welfare of the Society, he fitted out, at his own expense, an expedition to observe the Total Solar Eclipse in India in 1898, from which important scientific results were obtained; he enriched the equipment of three astronomical observatories in California by gifts of valuable instruments, and made generous financial contributions to this Society in time of need. For fifteen years he was the legal adviser of the Board of Directors of the Astronomical Society of the Pacific, and was ever prepared to give to the Society the benefit of his sound judgment and advice. In him this Society has lost one of its truest friends.

A committee appointed by President EDWARDS, consisting of Messrs. BURCKHALTER, CUSHING, and ZIEL, presented the following resolutions on behalf of the members of the Astronomical Society of the Pacific:—

In Memoriam.

WHEREAS, WILLIAM MONTGOMERY PIERSON, a Charter Member, an ex-President, and a member of the Board of Directors from the foundation of the Society, has been claimed by death; and

WHEREAS, Mr. PIERSON was foremost in promoting the welfare of the Society, by his wise counsel and generous financial aid; therefore be it

Resolved, That in the death of this distinguished citizen this community has suffered a severe loss, and this Society one that is irreparable; and astronomical science a friend, willing both to do and to give;

Resolved, That, whether as members of this Society or as his personal friends, we have each sustained an individual loss;

Resolved, That in token of our appreciation of his effective help and of our love for him, these resolutions be spread in full on our minutes, and that a copy thereof be sent with our heartfelt sympathy to the bereaved family of our departed friend.

SAN FRANCISCO, November 15, 1904.

ASTRONOMICAL SOCIETY OF THE PACIFIC.
CHARLES BURCKHALTER,
CHAS. S. CUSHING,
F. R. ZIEL,
Special Committee.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. Geo. C. Edwards . . . . *Preside*
Mr. S. D. Townley . . . . *First Vice-Preside*
Mr. Chas. S. Cushing . . . . *Second Vice-Preside*
Mr. A. O. Leuschner . . . . *Third Vice-Preside*
Mr. R. G. Aitken }
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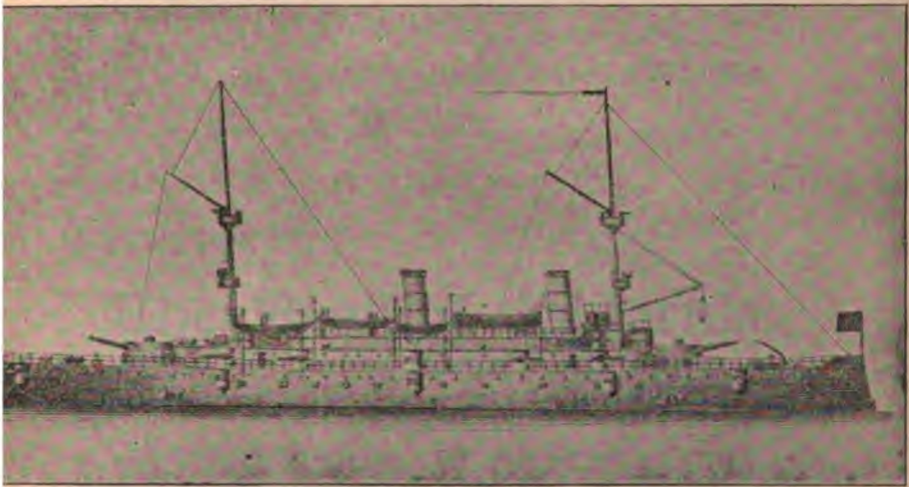

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